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9.

Notes on Tschudi's Types of Peruvian Birds.

HERBERT FRIEDMANN & H. G. DEIGNAN*

A little over a century ago, J. J. von Tschudi, the earliest important ornithological explorer of Peru, made a sizable collection of birds in that country. Among these specimens he found and described a large number of new forms, most of which are considered valid today. His collection went to the Museum of Neuchatel, Switzerland, from which institution, in 1866, the United States National Museum received 27 specimens of birds, mostly mounted—the consignment being marked "Types of Tschudi's Fauna Peruana." We have recently rediscovered these birds scattered through the collections and have made use of the occasion to go over them carefully.

We find that most of them must be regarded as types, or at least as cotypes. Tschudi described his new forms in the Archiv für Naturgeschichte, 1843 and 1844, and in his "Untersuchungen über die Fauna Peruana," 1844-46. In no case did he designate a definite specimen as the type or even intimate whether he had one or more specimens before him, or state an explicit, restricted, type locality. Inasmuch as his descriptions were all written after his collecting work was complete, it is reasonable to assume that all his birds were available to him at the time of his studies and that, therefore, in the absence of true holotypes, all of his paratypes (which would include all of his original series) must be considered as cotypes, except where the description, for one reason or another, does not fit a particular specimen.

Berlepsch & Hellmayr (*Journ. für Orn.*, 1905, pp. 6–20) reported on Tschudi's types in the museum at Neuchatel, apparently unaware of the fact that a considerable number of specimens had been sent away many years before. In fact, they merely discussed the Tschudi types they found at Neuchatel and made no comment on the forms described by Tschudi but no longer to be found there. The birds now in the United States National Museum fill in a good number of these omissions as well as revealing a number of cotypes of the forms still represented (in 1905) in Neuchatel. The specimens now in Washington, which we consider to be of type or cotype status, are listed below. Our specimens of forms which Berlepsch & Hellmayr found to be represented (by "type"—only three!) at Neuchatel in 1905 are considered cotypes; those which they failed to find at Neuchatel are, in lieu of other known specimens, considered to be types. If other specimens should be found in other museums, some of the types herein listed would, of course, become cotypes.

Penelope adspersa Tschudi = ***Ortalis guttata adspersa*** (Tschudi).

Archiv für Naturgeschichte, ix, (1), 1843, 386 (Peru, "frequenter in sylvis"; = eastern Peru).

Type: U. S. Nat. Mus. 41932; Perou.

Chapman (*Bull.* 117, *U. S. Nat. Mus.*, 1921, 44) writes that two males from Rio Cosireni have the throat and breast darker with the margins of the feathers whiter and more clearly defined than in examples from southeastern Colombia; and that, if the difference should prove to be constant, they should be known as *O. g. adspersus*. One of these Rio Cosireni birds is before us and agrees quite well with the unsexed type, except in having the upperparts more olive, less reddish-brown, and in being larger. The measurements of the two are as follows: type, unsexed, wing 185, tail 206, culmen from base 21 mm; Rio Cosireni, ♂, wing 203, tail 211, culmen from base 24 mm.

The type has the entire underparts slightly more brownish than the Rio Cosireni example, but its general brownishness may be partly due to foxing.

Charadrius Winterfeldi Tschudi = ***Aphriza virgata*** (Gmelin).

Archiv für Naturgeschichte, ix, 1843, 388 ("in Oceani Magni littoribus").

Type: U. S. Nat. Mus. 41933; original label lost, but locality entered in catalogue in 1866 as Valparaiso.

That Valparaiso, Chile, may be the actual type locality is not to be ruled out of consideration, as in his "Travels in Peru, Dur-

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ing the Years 1838-1842" (transl. by Thomasina Ross, 1849, p. 25), Tschudi describes birds seen for sale and at large in the harbor of Valparaiso on his way north to Peru, and he may have obtained his specimen of the surf bird there. The type is a bird in winter plumage and has the following dimensions: wing 162, tail 58, culmen from the base 26 mm.

Columba frenata Tschudi = *Oreopeleia bourcieri frenata* (Tschudi).

Archiv für Naturgeschichte, ix, (1), 1843, 386 ("in sylvis Antium declivitatis orientalis," Peru = eastern slopes of the Andes of Peru).

Type: U. S. Nat. Mus. 41931, unsexed; Perou; Wing 160.5, tail 94.5, culmen from base 21 mm.

The type is somewhat foxed. It has been compared with a male from Rio San Miguel, Peru, from which it differs in being more rufescent above, the rump and tail lighter and brighter, and in having the breast paler, much less grayish, more of a pale cinnamon drab and the sides, flanks, and under tail coverts much more rufescent. In his description of *O. b. subgrisea*, Chapman (*Amer. Mus. Novit.* no. 31, 1922, p. 2) refers to the underparts of his new form, ". . . as in *O. frenata*, the breast pale drab-gray instead of cinnamon-drab or drab; center of abdomen slightly paler than breast, pale smoke-gray rather than drab as in most specimens of *bourcieri;* lower tail-coverts grayer." This is rather confusing, as the type of *frenata* is the brownest of all on the underparts. The Rio San Miguel bird, which was identified as *frenata* by Chapman (*Bull.* 117 *U. S. Nat. Mus.*, 1921, p. 47) is intermediate between typical *bourcieri* (from El Roble and Almaguer, Colombia, and Zaruma, Ecuador) and the type of *frenata*. We have seen no specimens of *subgrisea* and can only call attention to the possibility of its range extending southward to northern Peru, making the Rio San Miguel specimen within its limits of variation, or the possibility of northern Peru and southwestern Ecuador being inhabited by variable intergrades between typical *bourcieri* and *frenata*, not constant enough to warrant nomenclatural standing.

Columba meloda Tschudi = *Zenaida asiatica meloda* (Tschudi).

Archiv für Naturgeschichte, ix, (1), 1843, 385 ("frequenter in regionibus calidis praecipue declivitatis Antium occidentalis" = western slopes of the Andes in Peru).

Type: U. S. Nat. Mus. 41930, unsexed; Perou; wing 177, tail 125, culmen from base 27.5 mm.

Conurus mitratus Tschudi = *Aratinga mitrata mitrata* (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 304 (Peru = Chanchamayo Valley; Zimmer, *Field Mus. Nat. Hist. Publ. Zool.*, ser. xvii, 1930, 263).

Type: U. S. Nat. Mus. 41926, unsexed; Perou; wing 189, tail 151, culmen from cere 31.5 mm.

Conurus rupicola Tschudi = *Pyrrhura rupicola* (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 304 (Peru).

Cotype: U. S. Nat. Mus. 41925, dismounted specimen, unsexed; "Perou"; wing 133, tail 100+, culmen from cere 16 mm.

Another cotype is in the British Museum (Cat. Birds Brit. Mus., xx, 1891, 225).

In his account of his journey, Tschudi (Travels in Peru, transl. by Thomasina Ross, 1849, p. 176) states that he found this bird together with the next one, abounding in the coastal region south of Lima, which may be taken as a more restricted type locality. The pose of the present (dismounted) specimen agrees with that in the figure of Tschudi's Untersuchungen Ueber die Fauna Peruana (Pl. 26, fig. 1).

Psittacus tumultuosus Tschudi = *Pionus tumultuosus* (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 304 (Peru).

Type: U. S. Nat. Mus. 41927, dismounted bird, unsexed; Perou; wing 171, tail 79, culmen from cere 26 mm.

The type locality may be more definitely stated as the coastal region south of Lima, where Tschudi writes (Travels in Peru, transl. by Thomasina Ross, 1849, p. 176) he found this parrot to abound ". . . in the valleys along the coast," and to ". . . commit great depredations in the maize fields."

Psittacus mercenarius Tschudi = *Amazona mercenaria mercenaria* (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 303 (Peru).

Type: U. S. Nat. Mus. 41928, unsexed; Perou; wing 198, tail 93, culmen from cere 30 mm.

Caprimulgus ocellatus Tschudi = *Nyctiphrynus ocellatus ocellatus* (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 268 (Peru).

Type: U. S. Nat. Mus. 41912, unsexed; Perou; wing 131.5, tail 122, culmen from base 20.5 mm.

Peters (Check-list Birds World, iv, 1940,

196) considers *brunnescens* Griscom & Greenway to need confirmation before recognizing it. We have a single Brazilian bird which by locality may be either *brunnescens* or *ocellatus* and find it to be duskier than the type of *ocellatus* as it should be according to Griscom & Greenway if it were *brunnescens* but otherwise it disagrees with their description, being brighter, more rufescent brown than *ocellatus*. These writers state that *brunnescens* has a general light chocolate brown coloration while *ocellatus* is bright rufous brown. The reverse is true of the two birds before us. The birds are of comparable antiquity, the Brazilian specimen being from the U. S. Exploring Expedition's collection, so there should be no differential foxing. The validity of *brunnescens* is therefore very doubtful, as individual variation seems to be greater than was supposed.

Capito glaucogularis Tschudi = ***Capito versicolor glaucogularis*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 301 (Peru).

Cotype: U. S. Nat. Mus. 41920, unsexed (female by plumage); Perou; wing 71.5, tail 81, culmen from base 22 mm.

While there seems to be no reason to consider this specimen as less likely a type than the others, it should be noted that in some details it agrees only approximately with the colored plate (plate 24, fig. 2 in Tschudi's Untersuchungen Ueber die Fauna Peruana). Thus, in the plate the crimson pectoral band extends entirely across the posterior end of the blue throat whereas in the specimen before us it is not quite so extensive; the green of the upperparts is lighter, slightly more yellowish in the bird than in the plate and the centers of the upper wing coverts not as dark as in the figure. The specimen, which is a "taken down" mounted specimen may, of course, have faded somewhat. It is also possible that the plate was made from another specimen, which is our reason for calling our bird a cotype.

A female of *versicolor* from Idma, Peru, is very similar to the type of *glaucogularis* and differs only in having the crown and occiput less yellowish and the yellow margin of the upper and posterior edges of the auricular area more distinct.

Chamaeza olivacea Tschudi = ***Chamaeza brevicauda olivacea*** Tschudi.

Archiv für Naturgeschichte, x, (1), 1844, 279 (Peru; restricted by Hellmayr, Cat. Birds Amer., iii, 1924, 293, to Montaña de Vitoc, Dept. Junin, Peru).

Type: U. S. Nat. Mus. 41916, unsexed, dismounted bird; "Perou"; wing 96.5, tail 65.5, culmen from base 22.5 mm.

Anabates montanus Tschudi = ***Anabacerthia striaticollis montanus*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 295 (Peru; = wooded region of Peru, between 10° and 12° South Lat.).

Cotype: U. S. Nat. Mus. 41923, unsexed, dismounted bird; "Perou"; wing 90, tail 75, culmen from base 17 mm.

Other cotypes exist in Neuchatel, and in the British Museum (Sclater, *Proc. Zool. Soc. Lond.*, 1871, p. 86).

In identifying the specimen we follow the nomenclature of Bangs (*Bull. Mus. Comp. Zool.*, lxx, 1930, p. 252) rather than of Hellmayr (Cat. Birds Amer., iv, 1925, 195).

Anabates ochrolaemus Tschudi = ***Automolus ochrolaemus ochrolaemus*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 295 (Peru = forest region of Peru, between 10° and 12° South Lat.).

Cotype: U. S. Nat. Mus. 41915, unsexed, dismounted bird; "Perou"; wing 83, tail 74, culmen from base 22 mm.

Other cotypes are in the British Museum and the Museum at Neuchatel.

Dendrocolaptes chunchotambo Tschudi = ***Xiphorhynchus chunchotambo chunchotambo*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 295 (Peru = Chanchamayo Valley, Peru).

Cotype: U. S. Nat. Mus. 41918, unsexed, dismounted bird; "Perou"; wing 103, tail 90, culmen from base 35 mm.

Other cotypes exist in the Neuchatel and British Museums.

The present specimen has been discussed by Zimmer (*Amer. Mus. Novit.* no. 756, 1934, p. 17).

Elaenia viridiflava Tschudi = ***Tyranniscus viridiflavus*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 274 (Peru = "coast region of Peru," errore = tropical zone of central Peru).

Cotype: U. S. Nat. Mus. 41921, unsexed, dismounted bird; "Perou"; wing 58, tail 48.5, culmen from base 9.5 mm.

There is another cotype in the museum at Neuchatel (referred to as the type by Hellmayr, Cat. Birds Amer., v, 1927, p. 474).

This specimen is paler above, the feathers without the darker centers, when compared with Tschudi's colored figure (Untersuchungen Ueber die Fauna Peruana, pl. ix, fig. 2).

Leptopogon superciliaris Tschudi = ***Leptopogon superciliaris superciliaris*** Tschudi.

Archiv für Naturgeschichte, x, (1), 1844, 275 (Peru = fringes of the forests of central Peru,—Montaña of Vitoc, Dept. Junin, Hellmayr, Cat. Birds Amer., v, 1927, p. 485).

Type: U. S. Nat. Mus. 41917, unsexed, dismounted bird; "Perou"; wing 75, tail 63.5, culmen from base 14.5 mm.

Pipra chloromeros Tschudi = ***Pipra chloromeros*** Tschudi.

Archiv für Naturgeschichte, x, (1), 1844, 271 (Peru = montañas of "northwestern" Peru; = valley of Vitoc, Dept. Junin; Hellmayr, Cat. Birds Amer., v, 1927, 25).

Type: U. S. Nat. Mus. 41924, unsexed (adult male by plumage), dismounted bird; Perou; wing 59, tail 24, culmen from base 10.5 mm.

Cyphorhinus thoracicus Tschudi = ***Leucolepis thoracica thoracica*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 282 (Peru = montañas of Uchubamba, near Vitoc, Dept. Junin).

Cotype: U. S. Nat. Mus. 41922, unsexed, dismounted bird; Perou; wing 68, tail 48, upper mandible broken.

This specimen is listed as a cotype rather than as a type because Hellmayr (Cat. Birds Amer., vii, 1934, p. 287) writes "(type in Neuchatel Museum)." Yet, Berlepsch & Hellmayr (*Journ. für Orn.*, 1905, 6–20), in their paper on the Tschudi types at Neuchatel, do not list this species.

Tschudi's colored figure (Untersuchungen Ueber die Fauna Peruana, 1846, pl. 16, fig. 1) is very poor. The type has the face, chin, throat, and breast much more rufescent and much brighter than the published figure.

Ptilogonys leucotis Tschudi = ***Entomodestes leucotis*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 270 (Peru).

Cotype: U. S. Nat. Mus. 41908, unsexed, dismounted bird; Perou; wing 106.5, tail 106, culmen from base 21 mm.

Baird (Rev. Amer. Birds, pt. 1, 1866, p. 432–433) has described this specimen in detail. He writes that the bird is one ". . . of Mr. Tschudi's types, presented to the [Smithsonian] Institution by the Museum of Neuchatel. It is moulting a considerable portion of its feathers, which somewhat obscures its characters, and it may even be a young bird not yet arrived at maturity." It does not seem probable that the specimen is immature. It apparently is an adult in moult, especially on the chin and sides of the head.

Berlepsch & Hellmayr failed to find any "type" of this bird in Neuchatel in 1905, but Hellmayr (Cat. Birds Amer., vii, 1934, 445) writes "type in Neuchatel Museum."

Tanagra analis Tschudi = ***Iridosornis analis analis*** (Tschudi).

Archiv für Naturgeschichte, x, (1), 1844, 287 (Peru = Valley of Vitoc, Dept. Junin; Hellmayr, Cat. Birds Amer., ix, 1936, 179, footnote).

Cotype: U. S. Nat. Mus. 41919, unsexed, dismounted bird; Perou; wing 82, tail 69, culmen from base 13 mm.

Another cotype exists in the British Museum (ex Sclater coll.) according to Sclater (Cat. Birds Brit. Mus., xi, 1886, p. 142). Hellmayr (Cat. Birds Amer., ix, 1936, p. 179) states "type in Neuchatel Museum," but in his earlier paper with Berlepsch, made no mention of this species among the Tschudi types still in that museum. Zimmer (*Field Mus. Nat. Hist., Zool. ser.*, xvii, 1920, 443) writes that the "type may have come from near Lima since Tschudi says . . . the species was common in the fruit gardens of Lima, he did not find it further north or east . . ." However, Hellmayr (cit. supra) writes (from subsequent knowledge of the range of the bird) that Tschudi's statement is a mistake, and suggests the restricted type locality given above.

Tanagra frugilegus Tschudi = ***Thraupis bonariensis darwinii*** (Bonaparte).

Archiv für Naturgeschichte, x, (1), 1844, 286 (Peru = prob. fruit gardens of Lima).

Cotype: U. S. Nat. Mus. 41913, unsexed, (male by plumage); Peru (original lavel lost); wing 85, tail 73, culmen from base 14 mm.

Another cotype went to the British Museum (Cat. Birds Brit. Mus., xi, 1886, p. 165).

Cissopis minor Tschudi = ***Cissopis leveriana leveriana*** (Gmelin).

Untersuchungen Fauna Peruana, Aves, 1846, p. 211 (wooded region of Peru; = Chacaybamba?).

Cotype: U. S. Nat. Mus. 41914, unsexed, dismounted bird; Chacaybamba, Peru; 4.8.39 (August 4 or April 8, 1839); wing 112, tail 135, culmen from base 20 mm.

The data as to place and date are on the original field label in what is probably Tschudi's own caligraphy. The other specimens listed in this paper have only the original museum exhibition labels, which this bird has as well, and which merely read —"Perou. Voyage de M. Tschudi."

Hellmayr (Cat. Birds Amer., ix, 1936, 439) states that the type (= another co-

type) is in Neuchatel Museum, but in 1905 he and Berlepsch failed to find it there.

Arremon frontalis Tschudi = ***Atlapetes brunnei-nucha brunnei-nucha*** (Lafresnaye).

Archiv für Naturgeschichte, x, (1), 1844, 289 (Peru = eastern wooded region between 8° and 9° lat. south and Jaen de Bracamoras, Peru).

Cotype: U. S. Nat. Mus. 41911, unsexed bird; original label lost; wing 79, tail 85, culmen from base 21 mm.

Although no type of this bird was found at Neuchatel in 1905 by Berlepsch & Hellmayr, the latter author (Cat. Birds Amer., xi, 1938, p. 413) states that a type is there. We therefore consider the present specimen a cotype.

Included with these types in the consignment from the Neuchatel Museum were four other Tschudi specimens which are not of type status. For the benefit of students wishing to unravel the synonymies of the species involved, they are listed below, together with references to the names under which Tschudi listed them.

Ortygonax rytirhynchus rytirhynchus (Vieillot).

Rallus caesius (not of Spix) Tschudi, Unters. Fauna Peruana, 1844-46, p. 301.

One spec., U. S. Nat. Mus. 41934, (Perou).

Columba plumbea delicata Berlepsch & Stolzmann.

Columba infuscata, Tschudi, Unters. Fauna Peruana, 1844-46, p. 275.

One spec., U. S. Nat. Mus. 41929, (Perou).

Thamnophilus melanochrous Sclater & Salvin.

Thamnophilus luctuosus (not of Lichtenstein) Tschudi, *Archiv. für Naturgeschichte*, x, (1), 1844, p. 278.

One spec., U. S. Nat. Mus. 41910, (Perou).

Molothrus bonariensis occidentalis Berlepsch & Stolzmann.

Icterus brevirostris (not of d'Orbigny and Lafresnaye) Tschudi, *Archiv. für Naturgeschichte*, x, (1), 1844, 292.

One spec., U. S. Nat. Mus. 41909, (Perou).

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10.

A Revision of the Kingfishers, *Ceyx erithacus* and *rufidorsus*.

S. Dillon Ripley

These two species of kingfisher are important members of the Indo-Malayan avifauna. For many years their identification has proved a stumbling block and a very large amount of literature has collected around them. The most recent discussion of the problem, that of Chasen & Kloss (1929), has served to clear up many difficulties. I believe, however, that one or two interesting facts remain to be pointed out, and it is in an effort to do so that I have turned to these species in this paper.

Kingfishers in general tend to show a constancy of plumage pattern which is striking. Certain characteristic colors reappear again and again. Some colors, as brown and yellow, seem to be closely linked and substitute for each other with great regularity. Plumage patterns are nearly uniform throughout the family. In the case of these two species of *Ceyx*, the color and size resemblances are so particularly close that the conclusion that these birds are very nearly related seems inescapable.

The next nearest relation of these two species is *Ceyx melanurus* with three races from the Philippines.

I am much indebted to Mr. J. L. Peters for reading over this manuscript as well as to the authorities of the United States National Museum, the Academy of Natural Sciences of Philadelphia and the American Museum of Natural History for the loan of specimens. In the following discussion all measurements are in millimetres, the wing pressed flat against the ruler, and the bill measured from the distal end of the external naris to the terminal point of the maxilla.

For easy identification of these two species, it might be well to insert here a key by which identification can be made.

A. Upper parts rufous with a lilac wash.
  - a. Forehead with a dark blue-black spot . . . . *C. erithacus.*
  - b. Forehead spot absent . . . . *C. rufidorsus.*
  - a′. A patch of ultramarine in the supraocular region . . . *C. erithacus.*
  - b′. Supraocular patch lacking . . . . *C. rufidorsus.*
  - a″. Scapulars black with an ultramarine wash . . . . *C. erithacus.*
  - b″. Scapulars rufous with a lilac wash . . . . *C. rufidorsus.*
  - a′″. Wing coverts black tipped with ultramarine . . . .*C. erithacus.*
  - b′″. Wing coverts rufous tipped with lilac . . . . *C. rufidorsus.*

Ceyx erithacus erithacus (Linnaeus).

Alcedo erithaca Linnaeus, Sys. Nat. 10, *T.* p. 115, 1758.

Description: For the adult bird see Sharpe (1892, p. 175). The rufous on the bend of the wing often extends to the lesser wing coverts.

Juvenal birds are distinguished from adults by several characteristic features. The bill is rather short and pale, often dusky at the base. On the upper surface the plumage is the same as the adult, but the scapulars tend to be tipped rather than washed with ultramarine. Instead of being washed with lilac, the feathers of the lower back sometimes are tinted with cobalt. The tail is often, but not invariably, tipped with black. Below, juvenal and immature birds show a very characteristic plumage. The throat is pure white not tinted with yellow. The lower cheeks, flanks, thighs, under tail coverts, and a band across the breast and upper abdomen are rufous, sometimes with an orange tint.

Measurements: Wing, ♂ 53–58.5 (55.8), ♀ 55–60 (56.8). Tail, ♂ 20–23.5 (22.6), ♀ 2.15–24.5 (23.1). Wing-tail index 38–42%. Bill, from naris, ♂ and ♀, 25–28.2 (27.2).

Range: Ceylon through the lowland coastal parts of India to Nepal, Assam, Burma, *fide* Stuart Baker (1927), the Malay Peninsula, Siam, Indo-China, southern China, Hainan, Andaman Ids, small islands in the Straits of Malacca and off the Malay Peninsula, coast of Sumatra.

Specimens Examined: Sixteen.

Discussion: This form is well established in continental Asia but only sparingly distributed among the islands. Such a distribution indicates a later origin than that of *rufidorsus* which has extended into the

Greater and Lesser Sunda area. The latter having become established in the Greater Sundas and adjacent islands, there has been a secondary infiltration perhaps in two waves by *erithacus*, which has succeeded in colonizing a few of the small islands not already reached by *rufidorsus* (Nicobars, Nias) and in competing with the latter species in the larger continental areas (Malay Peninsula, Borneo).

From the evidence afforded by specimens, Sumatra seems to be primarily the home of *rufidorsus*. I have examined the type of *Ceyx enopopygius* (Oberholser, 1912) and concur with Chasen & Kloss (1929) in their belief that it is an unusually bright immature specimen. The measurements of this specimen (wing 57.5, tail 23.5, bill 27.7) are not different from normal *erithacus*. The only other examples of *erithacus* from Sumatra are two males listed in Laubmann (1925). These three records are from coastal localities and this coupled with Robinson & Kloss' (1922) record of this species as being a bird commonly killed at one of the lighthouses in Malacca Strait leads me to suspect that the Sumatra records are accidental. These birds in contrast to *Ceyx rufidorsus* (Robinson, 1917) are subject to erratic local movements which result in isolated records appearing all over the islands of Malacca Strait and the adjacent Sumatran coast. This is a subject which should be studied more carefully. It is possible that some physiological dispersal mechanism is at work here which may be akin to migration.

Ceyx erithacus macrocarus Oberholser.

Ceyx erithacus macrocarus Oberholser, *Bull. 98, U. S. Nat. Mus.*, 23, 1917.

Description: Differs from *erithacus* by being larger. The forehead spot is smaller in two examples.

A nestling, A.M.N.H. 637008, is colored as the adult except for the reduction of the ultramarine wash on the scapulars back and median wing coverts to a series of spots. The shaft and the terminal part of the tail are black. Below the bird is similar to young of *erithacus*. This specimen was collected Oct. 4, 1905.

Measurements: Wing, ♂ 58–60.3 (59.4), ♀ 61. Tail, ♂ 23.–24 (23.4), ♀ 24.5. Wing-tail index 39–40. Bill, ♂ and ♀ 30–31 (30.4).

Range: Great Nicobar, Nicobar Ids.

Specimens Examined: Five.

Discussion: The most significant character of this race is its larger size, especially in bill measurements. It is interesting that the Andamans seem to be populated by typical *erithacus*. This is in contrast to the usual case in which Andaman and Nicobar populations tend to be identical. A single male from South Andaman (A.M.N.H. 637011) is characteristically of the smaller subspecies. This particular specimen is notable for a very heavy blue forehead spot which extends back broadly onto the crown.

In order to check on the above measurements, I have estimated the probability of these two populations being identical by use of the formula of T for deviations from the mean in small samples as discussed by Simpson & Roe (1939). This formula allows a very critical estimation when, as in this case, the combined samples of adult specimens are less than fifteen. By using the formula on the wing, tail, and bill measurements, T proves to be very significant for the bill (6.0), significant for the wing (3.1) and insignificant for the tail (1.5). Thus even on the basis of the bill alone, *macrocarus* is a justifiable race.

Ceyx erithacus motleyi Chasen & Kloss.

Ceyx erithacus motleyi, Chasen & Kloss, Festsch. für E. Hartert, *Journ. f. Ornith.*, p. 106, 1929.

Description: This and the following two races differ from *erithacus* and *macrocarus* by having the rufous tinted with lilac of the pileum and nape extending down on the back and continuous with the lower back and rump. The rest of the plumage, however, is similar to the typical subspecies.

The immature plumage differs from the adult as in *erithacus*.

Measurements: Wing, ♂ 57.5–60.5 (59.5). Tail, ♂ 22–24 (22.8). Wing-tail index 36–39. Bill, ♂ 28.5–30 (29.1).

Range: Borneo, Banguey Is, Labuan (?).

Specimens Examined: Five.

Discussion: The confusion resulting over the description of *Ceyx dillwynni* and *sharpei* from Borneo was finally resolved by Chasen & Kloss (1929). I believe, however, that they were mistaken in assuming Sharpe's plate of *dillwynni* (1868-71) to be a representation of an immature specimen of *rufidorsus*. I have before me two male adult specimens (M.C.Z. 197135, 197136) which correspond very closely to Sharpe's plate. I believe that they are hybrids between *rufidorsus* and *motleyi*. From a careful examination of the specimens it is difficult to escape the conclusion that where *erithacus* overlaps into the range of *rufidorsus*, hybridization has occurred. Indeed Sharpe had apparently already begun to suspect this by the time that he was working on the Catalogue of the Birds in the British Museum. In that volume (1892) he transfers his original description of *dillwynni* to a description of what is now *motleyi* and lists several dubious specimens which he remarks may be "in changing plumage . . . or are hybrids." A description of some of these specimens may be appropriate at this point.

(1). M.C.Z. 197135, ♂, ad. Kalabakang R., Borneo, coll. July 7, 1937. H. G. Deignan. Above this specimen is similar to typical *motleyi*, but the forehead spot is very much reduced as is also the supraocular patch of ultramarine. The capulars are washed with ultramarine, but tipped with pale lilac. The lesser and median wing coverts are strongly rufous (more so than in Sharpe's plate). The distal outer margins of the secondaries as well as the inner margins are edged with rufous. Below the bird is similar to the adult of either *rufidorsus* or *erithacus*.

(2). M.C.Z. 197136, ♂, ad. Kalabakang R., Borneo, July 14, 1937. H. G. Deignan. Above this specimen lacks any hint of forehead spot and again the supraocular patch of ultramarine is nearly gone. The scapulars are as in *motleyi*, but some of the upper median wing coverts are rufous and the greater wing coverts and outer margins of the secondaries are irregularly tipped with rufous.

(3). M.C.Z. 197134, ♂, ad. Sandaken, Borneo, June 18, 1937. H. G. Deignan. Above this specimen is uniformly rufous with a lilac wash. There is no trace of either forehead or supraocular spot. The scapulars present a curious violet tone from the mingling of ultramarine and lilac washes. The lesser median wing coverts are rufous. The greater wing coverts are black with a bluish-lilac subterminal wash and rufous edgings. This bird stands almost exactly in an intermediate position between *motleyi* and *rufidorsus*.

(4). M.C.Z. 69608, ad. Linibang, Sarawak, Borneo, no date. Above this bird has a forehead spot and supraocular spot. The scapulars are, however, predominately rufous-lilac. The lesser and median wing coverts are rufous, the greater strongly tipped with ultramarine.

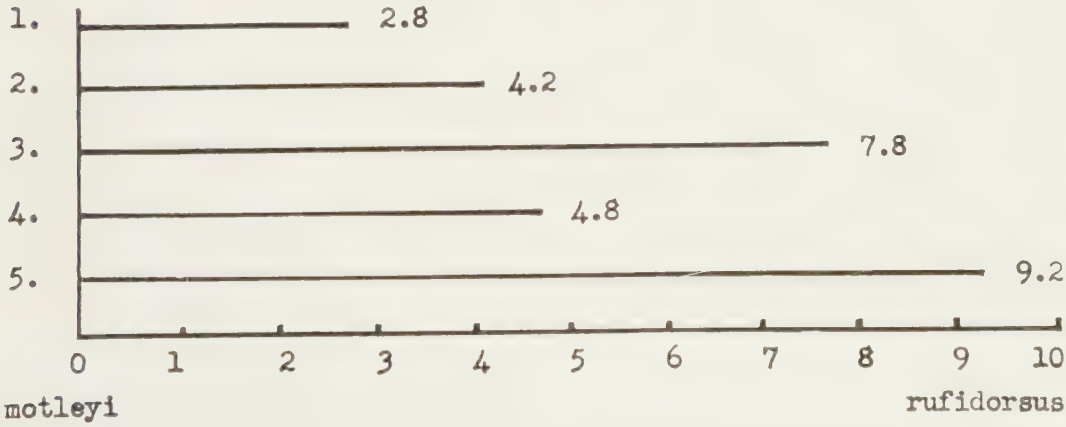
(5). M.C.Z. 69610, ad. Borneo, 1915. H. W. Smith. Above this bird is similar to *rufidorsus*. However, it is an adult specimen and so should not have curious patchy blackish and ultramarine tinted scapulars. The wing coverts are similar to *rufidorsus* except that there is a hint of ultramarine on the tips of some of the greater one.

(6). M.C.Z. 69609, o im., Kuala Treban, Sarawak, Borneo, Feb. 28, 1918. An immature hybrid is of interest. Above this specimen shows a prominent forehead spot and the merest trace (two feather tips) of a supraocular patch. The scapulars are black with a few faint tips of ultramarine. The lesser and median wing coverts are largely rufous, the greater are black, washed with ultramarine and with faint rufous edgings. Below this bird is typically immature, having a white throat and strongly rufous cheeks, flanks, and breast band.

The above specimens represent almost a complete transition from *erithacus motleyi* to *rufidorsus rufidorsus*. Each bird represents a greater or less blending of the distinctive characters of the two species. Here indeed is an interesting example of two closely related forms of kingfisher which do not quite satisfy any of the concepts of taxonomy or speciation. On the one hand the color of the back is so different that many taxonomists would consider these birds to belong to two species. Others might lump them, if it were not for the over-lapping of their ranges. From the speciation point of view they do not conform either to a Superspecies or to a *rassenkreis*. And yet the birds would satisfy any geneticist as to their close ancestry by their apparent readiness to hybridize.

Shown on a linear scale, the characters of these hybrids indicate quite clearly their intermediate position. Letting certain caracters equal certain numbers we arrive at an arbitrary scale as follows:

	erithacus motleyi	*rufidorsus rufidorsus*
Forehead spot	present—0	absent—10
Supraocular spot	present—0	absent—10
Scapulars	blue—0	rufous lilac—10
Lesser & median wingcoverts	black—0	rufous—10
Greater wing coverts	black—0	rufous—10



Text-fig. 1. The numbers on the left are those of the individual specimens. The base line represents the scale from *motleyi* to *rufidorsus*. At the end of each specimen's line is the figure representing the sum of its characters.

By adding up each specimen's score and dividing by five we arrive at the following:

The original description of *Ceyx dillwynni* Sharpe (1868) would have sufficed for the local race of *erithacus,* if it had not been for the fact that not only did Sharpe not mention a supraocular patch as occurring on his type, but Salvadori (1869) specifically says that it did not have one. I cannot find a single undoubted specimen of the species *erithacus* which does not possess this spot. Any specimen, therefore, coming from Borneo or Sumatra or the Malay Peninsula (as will be seen later) which is an adult but does not possess either the forehead spot or supraocular patch, and yet which has ultramarine on scapulars or wing coverts must be considered to be potentially a hybrid.

Ceyx erithacus captus Ripley.

Ceyx erithacus captus Ripley, *Proc. New Eng. Zool. Club,* **XIX**, 15, Dec. 29, 1941.

Description: This race differs from *motleyi* by its longer bill and slightly larger size, and by reduction of the forehead spot which is lacking in one specimen. This last character was not mentioned in the original description due to the fact that the question of the hybrid population of *motleyi* has not been elucidated.

From *erithacus* this race differs as *motleyi.*

I have seen no immature specimens.

Measurements: Wing, ♂ 59.5–62.5 (60.8). Tail, ♂ 23–24 (25.6). Wing-tail index 39–40. Bill 32–33.5 (32.6).

Range: Nias I. West Sumatra.

Specimens Examined: Three.

Discussion: It is interesting to note that *captus,* as *macrocarus,* differs from its nearest relative by size. In this case it is the bill which is notably larger. Like *macrocarus,* also, the forehead spot and the supraocular patch are much reduced.

Ceyx erithacus vargasi Manuel.

Ceyx erithacus vargasi Manuel, *Phil. Journ. Science,* **69**, No. 4, 383, Aug., 1939.

Description: Differs from *motleyi,* which it otherwise closely resembles, by the reduction of the lilac wash on the upper surface. In the specimen examined this wash occurs only in a supraorbital stripe ending in an ultramarine supraocular patch, and on the lower back, two areas where the color is most highly concentrated in *motleyi.* The ultramarine wash on the scapulars also is reduced to the tips of one or two feathers. The specimen examined, though otherwise in adult plumage, has a black shaft and a black stripe along the middle of the terminal half of the tail feathers.

Measurements (one female): Wing 56.5. Tail 24. Wing-tail index 42. Bill 28.5.

Range: Mindoro I., Philippine Islands.

Discussion: The existence of this population of *Ceyx erithacus* was only discovered in 1939 by Manuel who noticed that two specimens of *Ceyx* had the blue supraocular patch not found in *rufidorsus.* It is worth noting that *Ceyx melanurus* behaves in a strictly representative way in the Philippines with *rufidorsus,* while *erithacus* has incurred on the range of *rufidorsus* on Mindoro.

Ceyx rufidorsus rufidorsus Strickland.

Ceyx rufidorsa Strickland, *Proc. Zool. Soc.,* p. 99, 1846.

Ceyx innominatus Salvadori, *Atti R. Accad. Sci. Toririo,* **IV**, p. 465, 1869.

Description: Above, rufous washed with lilac, scapulars and wing coverts as the back, primaries black, the first edged with rufous, secondaries black edged with rufous. Ordinarily this species lacks a dark forehead spot (three times present in 25 examples) and an ultramarine supraocular patch (twice present in 25 examples). Below the throat is white, the rest of the underparts being rich yellow.

Immature birds differ from the adult by having less of the bright lilac wash on the rufous upper parts. A nestling (A.M.N.H. 637014) from Gunong Tahan, Pahang, Malay Penin., collected in November, has black scapulars tinted with rufous and with one or two faint spots of ultramarine. The wing coverts tend to have rather more black than the adult. The tail is entirely rufous. Below the throat and belly are white, the cheeks, flanks, and a band across the abdomen rufous.

An immature male from East Java (A.M.N.H. 637034) collected in August, has completely rufous scapulars. This bird is one of the specimens which has an ultramarine spot above the ear. Below it agrees with the other specimens.

An immature female from Borneo (A.M.N.H. 637055) collected in September, has blackish scapulars overlaid with rufous and a black-tipped tail.

Measurements (adults): Wing, ♂ 56.5–60.5 (58.2), ♀ 59.5–60.5 (60). Tail, ♂ 22.7–25 (23.7, ♀ 24–24.7 (24.2). Wing-tail index 39–41. Bill, from naris, ♂ and ♀, 27–32 (28).

Range: Malay Peninsula, Rhio and Lingga Islands, Banka, Billiton, Sumatra, Siberut, Sipora, Java, Bali, Lombok, Sumbawa, Flores, Kangean, Bawean, Borneo, North Natuna, Anamba Ids, and Philippines, Palawan, Balabac, Mindoro, Tawitawi, Bongao, Calamianes.

Specimens Examined: Twenty-one.

Discussion: Several specimens from the Malay Peninsula and Sumatra have been noted which appear to be hybrids.

(1). An adult female (A.M.N.H. 637027) from the Deli district of Sumatra, Van Heyst coll., has a prominent forehead spot

and an infusion of ultramarine in the supraocular area. The scapulars, lesser and median wing coverts are mixed with black and ultramarine.

(2). Another adult female (M.C.Z. 17707) from Benkoolen, Sumatra, has a prominent forehead spot and blackish scapulars and wing coverts irregularly spotted with traces of ultramarine.

(3). A juvenal male (U.S.N.M. 180199) from Kateman River, E. Sumatra, collected in August, has the forehead spot and black tipped with ultramarine scapulars of *erithacus,* but it lacks the supraocular patch. The terminal half of the tail along the shaft of the feathers is black.

(4). An immature specimen from Great Karimon Id., E. Sumatra, (U.S.N.M. 180198) collected in May, has a black forehead patch and mixed scapulars, black and rufous, with lilac and ultramarine spots.

(5). A male molting into adult plumage (A.M.N.H. 637012) from western Pahang, Malay Peninsula, collected in January, has the blue forehead spot and supraocular patch of *erithacus*. However, the wing coverts, as in some of the Bornean hybrids, are mainly rufous.

These specimens indicate clearly that wherever the range of these two species overlap, there is a pronounced tendency to hybridization. From them it is clear that any specimen from Sumatra, the Malay Peninsula or Borneo, which seems to be adult but has either of the following combinations, must be suspect.

Hybrid Type A: Forehead spot and supraocular patch present, but scapulars and wing coverts largely rufous.

Hybrid Type B: Forehead spot and supraocular patch absent, but scapulars and wing coverts largely black with an ultramarine wash.

Specimens from Java tend to be slightly smaller, but tests for the significance of these data by the formula of *T*, show that the differences are not valid and the name *innominatus* cannot be upheld.

Ceyx rufidorsus jungei ssp. nov.

Type: M.C.Z. no. 178157, ♂ ad., collected by E. Jacobson and W. C. vanHeurn, July 28, 1913, Ajer Dingin, Simalur I.

Diagnosis: From *C. r. rufidorsus* this race differs by its larger size.

Measurements (of type): Wing 62, tail 26, bill 31.5; (of series): Wing, ♂ 62–64.5 (63.2), ♀ 62.5–63.5 (63). Tail, ♀ 25–26 (25.5), ♀ 25.5–26.5 (26). Wing-tail index 39–42. Bill, ♂ and ♀, 30.5–32 (31.3).

Range: Simalur and Batoe Ids, Tanah Massa and Tanah Bala.

Specimens Examined: Seven.

Discussion: This race is decidedly larger than *rufidorsus* from the rest of the range. It is interesting to note that the bill measurements, though averaging larger, are not significantly so when the probability is computed by standard deviation. Birds from Siberut and Sipora, as listed by Chasen & Kloss (1926), agree in size with typical *rufidorsus*. Here again, as in the two races of *Ceyx erithacus* on small islands north and west of Sumatra, this population of kingfishers differs from its nearest relatives by larger size. This race is named in honor of Dr. G. C. A. Junge of the Leiden Museum who has always been interested in East Indian birds.

Conclusion.

Ceyx erithacus and *rufidorsus* are closely allied species and might be considered conspecific were it not for the fact that their ranges are overlapping. In the Malay Peninsula, Sumatra and Borneo where this occurs, specimens were examined which show hybrid characters indicating that the earlier confusion in the nomenclature was probably due to this phenomenon. *Ceyx rufidorsus* is considered to be the older species due to its more extensive range.

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11.

On the Reproduction of *Gobiosoma robustum* Ginsburg.

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(Plates I & II; Text-figure 1).

Introduction.

The small and active goby, *Gobiosoma robustum* Ginsburg, inhabits a wide range of territory on the west coast of Florida near the field station of the New York Aquarium located on Palmetto Key. There appears to be nothing whatever in the literature on the habits or behavior of this common fish. The observations and data presented herewith were gathered incidental to studies of the life histories of other species in this region (see Breder 1939a and b, 1941a and b). Mr. M. B. Bishop of Yale University, Mr. L. A. Krumholz of the University of Illinois and Mr. B. Dontzin of Cornell University all rendered valued assistance in connection with this study.

This species, differentiated from related forms by Ginsburg (1933), represents the only member of the genus found occuring near the laboratory. Here it is abundant and may be taken in numbers among the mangrove roots and on open sandy beaches. Dredging brought it up from depths as great as twenty feet, which represents the deepest of this shallow bay in the vicinity of the laboratory. It was taken in such equipment over all of the various types of bottom, such as grassy places, sponge beds, scallop beds, sand bars and even over soft spots of flocculent mud.

The individuals of this form are exceedingly variable. Fowler (1941) figures six patterns represented in his material. Some of the pattern differences are referable to sex but they are so overlaid with individual vagaries that exact description becomes difficult. Nevertheless with a little experience it is possible to sex individuals with reasonable accuracy.

Shropshire (1932) figures the young of a *Gobiosoma* under the name *Gobiosoma molestum*. It is impossible to tell just which form, under present terminology, he had. *G. molestum* Girard is now a synonym of *G. bosci* (Lacépède) but as Shropshire thought his material was not the latter it is possible that he was actually dealing with *G. robustum* as here understood.

There is no confusion about the identity of the present material as the fish were taken guarding their eggs and furthermore all other specimens in our collections are referable to this one species, and it is the only form definitely known to be living in the vicinity. Dr. I. Ginsburg, the describer of *G. robustum,* was good enough to check over this material and compare it with his large series of both species.

Nesting and Nesting Sites.

Gobiosoma robustum may be found with its eggs from March to June, at least. At first this finding led to the assumption in the field that there were more than one species included. However, since a critical study of the incubating fishes shows them to be referable to a single species, it follows that this form has a long spawning period which reaches from the coldest to the warmest period of the year. It may well be that actually spawning is in progress at all times, which, if true would account for the relatively small number of nests encountered at any one time, compared with the abundance of individuals in the region.

The nests so far located have all been in shells or sponges. Usually the eggs are found hanging from the underside of some surface, but are not necessarily in such a position. Plate I, Figure 1, shows the two valves of a *Pecten* shell with the eggs attached to what had been the lower shell and the guarding male with them. This fish continued caring for the eggs with the shell in its open position.

Courtship and Parental Care.

Apparently only the males guard the eggs, as females have never been found in

the vicinity of nests. The males fan and work over the eggs in a manner reminiscent of a fresh water darter. Beyond this nothing was noted in the matter of specialized behavior. Although the males would attack small animals, such as other gobies, the slightest disturbance of a larger sort would usually cause them to retire. They would return as soon as the disturbance subsided.

Although we were not successful in having this species spawn in aquaria, several males established themselves in sheltered places which they would defend against the intrusion of their tank mates. From such locations they would sally forth to court nearby females. This was done with much spreading of the fins, especially the dorsal, accompanied by short darts near or at the female. This was usually carried on until she retreated. The coloration of the male at these times became intense and dark, nearly black, in most cases; most notably so on the widely extended first dorsal fin.

The largest male seen was 34 mm. in standard length. This is the fish shown in Plate I. The smallest mature and ripe male seen was 16.5 mm. Ripe females examined ranged from 16.5 to 21.5 mm. Apparently the males not only reach a larger size but average somewhat larger than the females as well. Smaller individuals grading down to those of a few millimeters are present both summer and winter, again indicating a long if not continuous reproductive season.

The Eggs.

The elongate eggs are attached by one end to a matted base of adhesive threads. They are evenly elliptical but there is an apparent seasonal difference in their proportions. Those taken in March average rather differently than those taken in June according to the following schedule, measured on living eggs and given in mm.

		Length			Width		
No. of eggs	Months	Average	Maximum	Minimum	Average	Maximum	Minimum
8	March	1.62—	1.70	1.55	0.62—	0.70	0.60
2	June	1.35	1.40	1.30	0.50	0.50	0.50
10	All	*1.57*	*1.70*	*1.30*	*0.60*	*0.70*	*0.50*

These differences would seem to be referable to seasonal effects, probably chiefly temperature, controlling the speed of development of the ovarian eggs. Another possible interpretation is that this is an expression of incipient speciation, starting first with a prolonged spawning season finally reaching over the extremes of summer and winter temperatures. Those fish most responsive to temperature variations, at either end of the long season, might be beginning to show slight differences in reproductive items, in this case egg size, finally leading to the establishment of two fairly distinct forms with, perhaps, intermediates dropping out. In this connection the differences in the spawning times of *Opsanus tau* and *Opsanus beta* discussed by Breder (1941a) is suggestive.

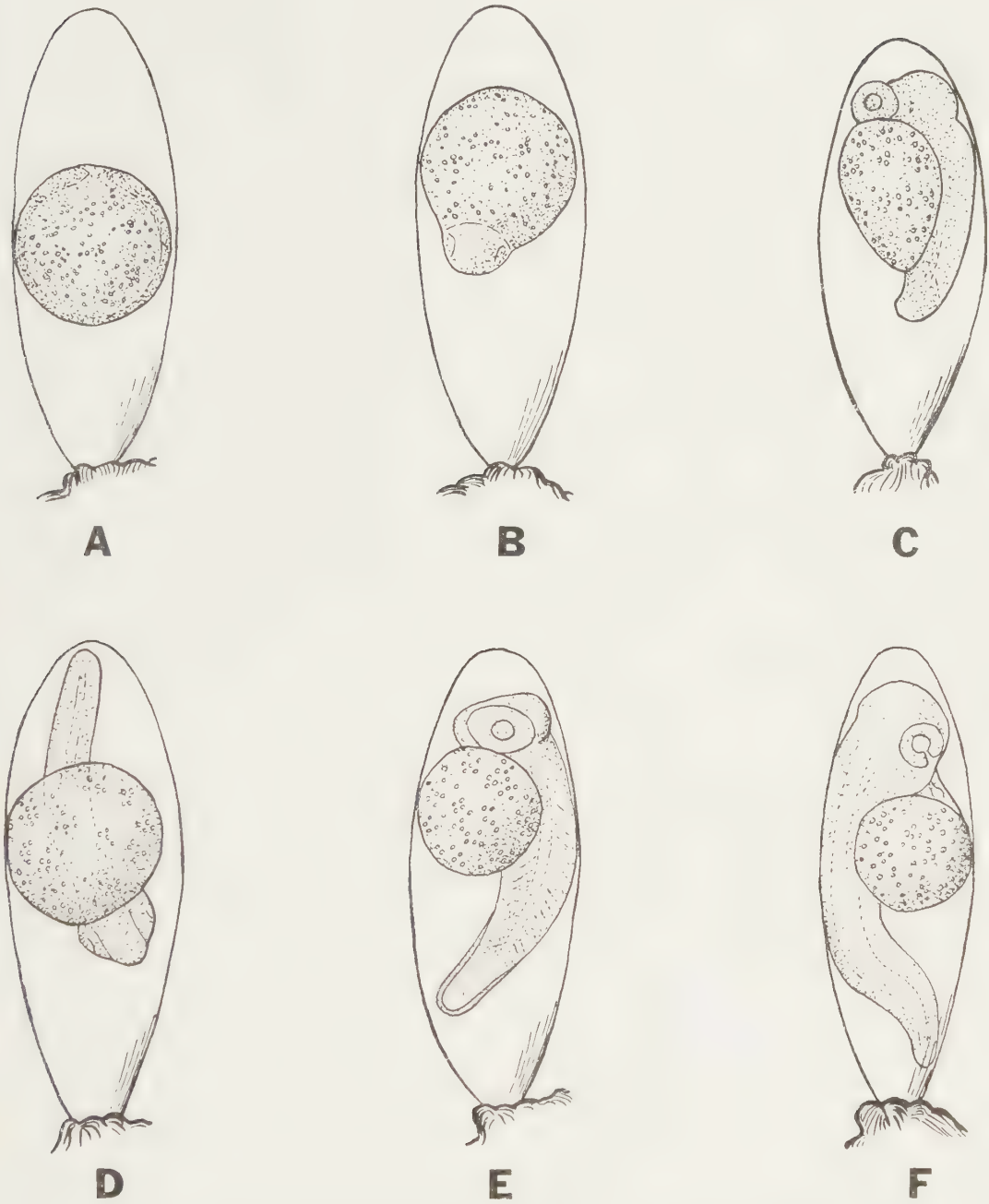
The winter eggs are shown in six stages of development in Text-fig. 1. When first found they appeared as in "A," March 14, 3:45 p.m. The yolk and germinal parts are opaque and slightly yellowish. The elliptical envelope is clear and without markings. Attachment is at one end by means of a tangled mass of adhesive strands. The nature of this material is better shown in the photographs of Pl. II. In many of the eggs the yolk was nearer to the upper tip than to the center. Numerous exceedingly small droplets, hardly visible at lower powers, were scattered over the surface of the yolk as indicated in the sketches. Twenty-two and a quarter hours later the eggs appeared as shown in Text-fig. 1, "B." At this stage the swelling of the large head was especially prominent. In an additional twenty-six and a quarter hours the embryo was well formed and appeared as in Text-fig. 1, "C." Both yolk and embryo presented an opaque appearance. After twenty and one-quarter hours more the embryo had reached the proportions shown in Text-fig. 1, "D." At no time was there a sufficient transparence to evidence much of the internal structure. The side view seen in Text-fig. 1, "E," when the egg was twenty-one hours more advanced, shows some of the vertebral fragmentations. By the time an additional twenty-seven and one-half hours had passed the heart was evident and beating slowly and the tail gave spasmodic twitches.

These figures cover a period of 117¼ hours during which time the temperature in the incubating dishes ranged from 15.5 to 18.5° C. It was noted that some of the eggs were not as advanced as others, indicating at least more than one spawning. These figures are based on the youngest eggs. By the time the last stage was reached they were practically equal, so far as gross examination was concerned. Plate II, Figures 2 and 3, give some indication of the differences in the extent of advancement of the eggs, especially if compared with the sketches of Text-fig. 1.

By March 24 all the eggs were dead, presumably due to extreme temperature fluctuations in the laboratory.

Discussion.

The development of the eggs of *Gobiosoma bosci* (Lacépède) has been described in de-



Text-fig. 1. Stages in the development of the eggs of *Gobiosoma robustum*. Camera lucida sketches of living material. **A.** An early egg as found in nest. **B.** 22¼ hours older than "A," with cephalization well advanced. **C.** 48½ hours older than "A," with the tail reaching well beyond the yolk. **D.** 68¾ hours older than "A." **E.** 89¾ hours older than "A." **F.** 117¼ hours older than "A," with the heart beating and the embryo showing activity.

tail by Kuntz (1916) and discussed at length by Hildebrand & Cable (1938). A comparison of the present notes on *G. robustum* with these papers shows the details to be quite similar, as would be expected on two such close species. The eggs of the latter average slightly longer and wider than those of *G. bosci*, as is indicated by the following tabulation of ranges in size, given in mm.

Species		Long Diameter	Short Diameter
G. bosci		1.15–1.37	0.57–0.59
G. robustum	All	1.30–1.70	0.50–0.70
	Summer	1.35–1.40	0.50–0.50
	Winter	1.62–1.70	0.62–0.70

It will be noted that the summer measurements are closer to those of *G. bosci* than those of the winter. The *G. bosci* material was likewise taken in summer. Hildebrand & Cable (1938) found young from May to December on the North Carolina coast, indicating a long season for this species also but with a winter interruption which is probably more a matter of geography and temperature than a specific difference. This strengthens the view that spawning may take place throughout the year on the much warmer Florida west coast. They found the young sometimes in the surface tows but more frequently in the bottom tows, indicating that they do not spend much time as plankton, an item also noted in the *G. robustum* material. Dip nets have found them in very small sizes clinging to floating drift, such as bits of plant stems, and it seems that most specimens taken in surface tows come from such locations, as even in very small sizes they sink rapidly and are not given to much active swimming other than short darts between supporting objects. Apparently sustained swimming is a considerable effort for these fishes.

The eggs of *Gobiosoma* and a number of related genera are remarkably similar as are their reproductive habits and it would be pointless at this place to discuss the perhaps minor differences of uncertain clarity until much more is known in greater detail about more of the numerous species.

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EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Male *Gobiosoma robustum* guarding nest in an opened scallop shell.

Plate II.

Fig. 2. Photomicrograph of the living eggs in about the stage shown in Text-figure 1, A.

Fig. 3. Photomicrograph of the living eggs in about the stage of Text-figure 1, E.

FIG. 1.

ON THE REPRODUCTION OF *GOBIOSOMA ROBUSTUM* GINSBURG.

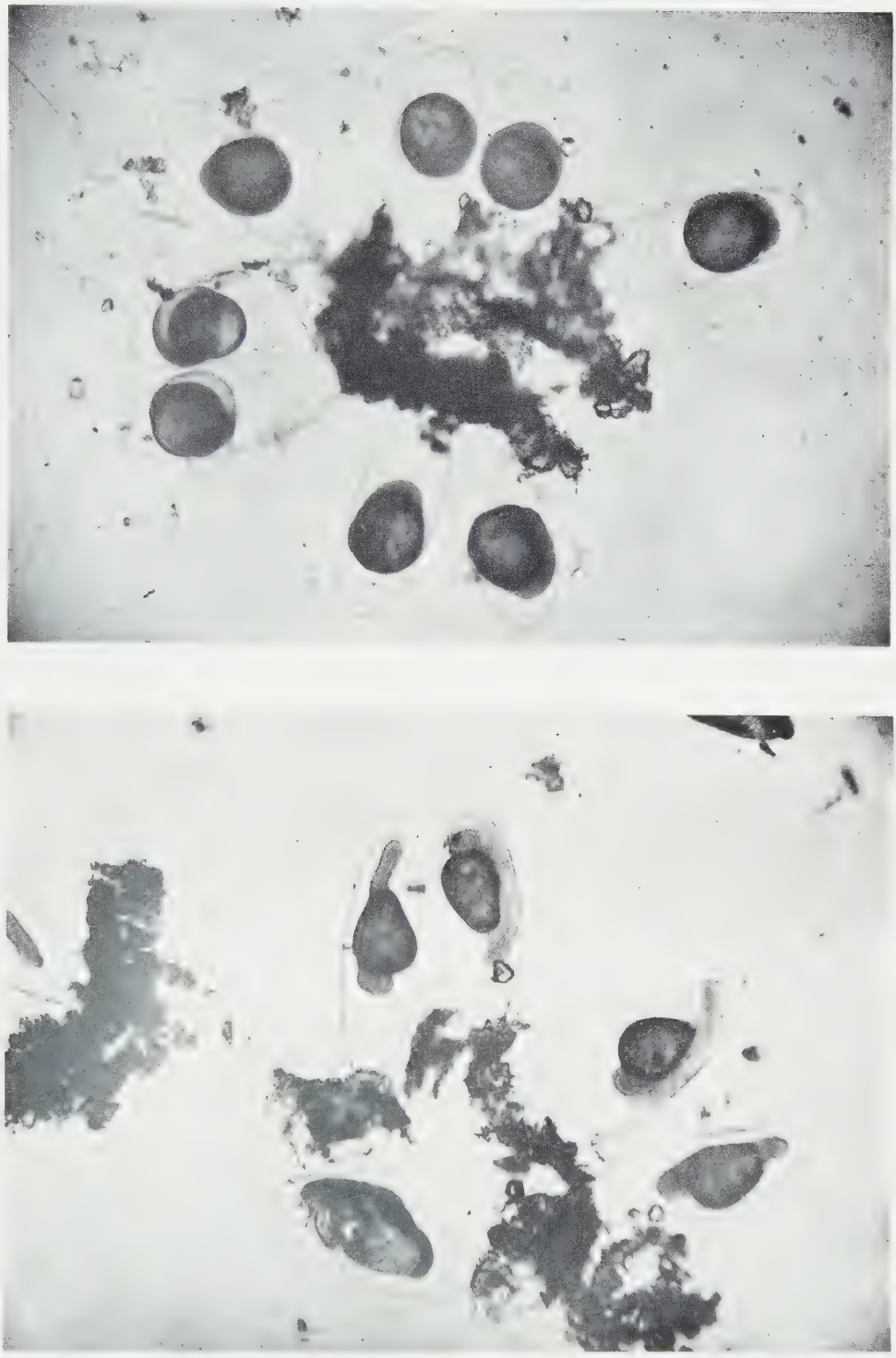

FIG. 2.

ON THE REPRODUCTION OF *GOBIOSOMA ROBUSTUM* GINSBURG.

12.

Trichodina spheroidesi and *Trichodina halli* spp. nov. Parasitic on the Gills and Skin of Marine Fishes, with Special Reference to the Life-history of *T. spheroidesi*.

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&

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Plates I–III; Text-figures 1–4.

INTRODUCTION.

Marine members of the family Urceolariidae have been described from several species of invertebrates and vertebrates. Among those parasitizing fish are the following: *Trichodina scorpaena* Robin (1879) from the gills of *Scorpaena* and *Trigla; T. labrorum* Chatton (1910) from two species of *Symphodus;* and, *T. fariai* da Cunha & Pinto (1928) from the intestine of the smooth puffer, *Spheroides testudineus.* Fantham (1918, 1919, 1924, 1930) reported *Trichodina* from several fishes of which the following were definitely identified as new in his 1930 paper: *Trichodina clini* from *Clinus taures, C. superciliosus, C. capensis, C. cottoides, C. anguillaris, Pristopoma bennettii* and *Box salpa; T. blenni* from *Blennius cornutus, T. mugilis* from *Mugil capito* and *T. chelidonichthys* from *Chelidonichthys cupensis.*

Because of insufficient information on many of the above forms, it was extremely difficult to arrive at a definite conclusion as to the validity of these species. In the present studies, the writers encountered two forms of *Trichodina* parasitic on the gills and skin of puffers (*Spheroides maculatus*) and other marine fishes from the New York and New Jersey coast. These peritrich ciliates are easily distinguished from one another on absolute size and other characters. The one, a smaller and more abundant form, is designated *Trichodina spheroidesi.* The other, larger in all respects and less frequently encountered, is called *Trichodina halli.* This species can easily be distinguished from other *Trichodina* infesting marine fishes on the basis of body size and size and relationships of the organelles (see Table).

MATERIAL AND METHODS.

Between the months of June and the early part of October, from 1938 to 1940, about three hundred of the puffers taken in pound nets in Sandy Hook Bay were examined for *Trichodina.* Two hundred and forty-eight, or 82%, of the fish were found parasitized, the intensity varying considerably.

A number of gill samples were fixed in Schaudinn's fluid without acetic acid, and others were fixed in 10% neutral formalin. The material was stained with Heidenhain's iron-hematoxylin and Mallory's triple stain. A few samples of those treated by the former method were counterstained with "light green." Only the Schaudinn-fixed specimens were found suitable for cytological studies. Studies on the adhesive disc and denticulate ring were made from both the Schaudinn and formalin fixed material.

A combination of the Klein's (1926) silver impregnation and the De Fano's reduction techniques was used to determine the ciliary pattern. Especially good results for such studies were obtained with material fixed with formalin. The samples were washed in five changes of distilled water, impregnated with a 5% solution of silver nitrate for a period of eight to twelve hours, and placed in darkness. Following the removal of excess silver nitrate solution the material was reduced in De Fano's solution. The films were tones in a 3% solution of sodium hydrosulphite and sodium anthraquinone sulphonate (25:1). This method,

although not delicate enough to give a distinct silver line system, nevertheless effectively demonstrated the ciliary pattern, including the basal granules.

Measurements were taken of the height, the diameter of the organism, the diameter of the adhesive disc and of the denticulate ring. A count was made of the hook number on all mounted organisms.

Host-Parasite Relationships.

A variety of fishes indigent to the Sandy Hook area were found to harbor *Trichodina* (Nigrelli, 1940). The infestation on any one host species was never found as consistently or as intense as on the puffers. Insofar as could be determined, trichodiniasis among puffers was limited to fish on the New York and New Jersey coast, for examination of this species from the coast of Massachusetts during part of the period of this investigation did not reveal infection.

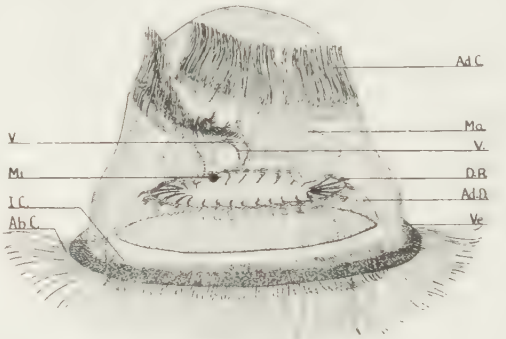
A few migratory *Trichodina* were found moving about on the body surface of puffers. However, the heaviest infestation was always on the gills. This may be attributed to the small opercular opening which encourages the concentration of these ciliates in the gill chamber.

The presence of red blood cells in food vacuoles of the parasites show that they are capable of considerable tissue destruction. This is indicated further by the fact that in exceptionally heavy infestation the gill epithelium was completely destroyed, leaving large denuded areas among the filaments. Such a condition results in the death of the host.

Trichodina spheroidesi sp. nov.

(Text-fig. 1).

Description: Organisms turban shaped. Diameter ranges from 17–54 μ; height from 12–42 μ. Two parallel rows of adoral, long, flexible, closely set, cilia present; cilia begin a short distance from the base of the peduncle, make one and a quarter clockwise, spiral turns and terminate in the vestibulum just above the mid-sectional plane of the oral surface; cilia, shortened noticeably at a point near the entrance of the vestibulum, spirals twice along the wall of the vestibulum and at the lower end are twisted together; direction of this spiral, when viewed from the end of the vestibulum outward, also clockwise. Aboral region with two rings of cilia; one ring, fused to form a membranelle, attached to inner posterior surface of the velum; second ring of cilia, found between membranelle and outer surface of the adhesive disc, are more delicate and approximately half as long as those forming the membranelle. Adhesive disc is a deep saucer-shaped organelle, ventral in position, bordered on the dorsal side by the denticulate ring and on the posterior side by the inner row of cilia; diameter of adhesive disc ranges from 18–32 μ; striae, present on inner and outer walls of the disc, are argentophilic. Denticulate ring non-argentophilic; diameter of the ring varies from 14–22 μ; denticles of the ring with hooks on outer border and slender rays on inner border, joined together by triangular projections (Text-fig. 4); number of hooks varies from 21–31. Macronucleus is typically horse-shoe



Text-fig. 1. *Trichodina spheroidesi*. Side view. × 950. Semi-diagrammatic reconstruction from hematoxylin and silver nitrate preparations. **Ad. C.**, adoral cilia; **V.**, vestibulum; **Ma.**, macronucleus; **C. V.**, contractile vacuole; **Mi.**, micronucleus; **D. R.**, denticulate ring; **Ad. D.**, adhesive disc; **Ve.**, velum; **I. C.**, inner ring of aboral cilia; **Ab. C.**, outer ring of aboral cilia.

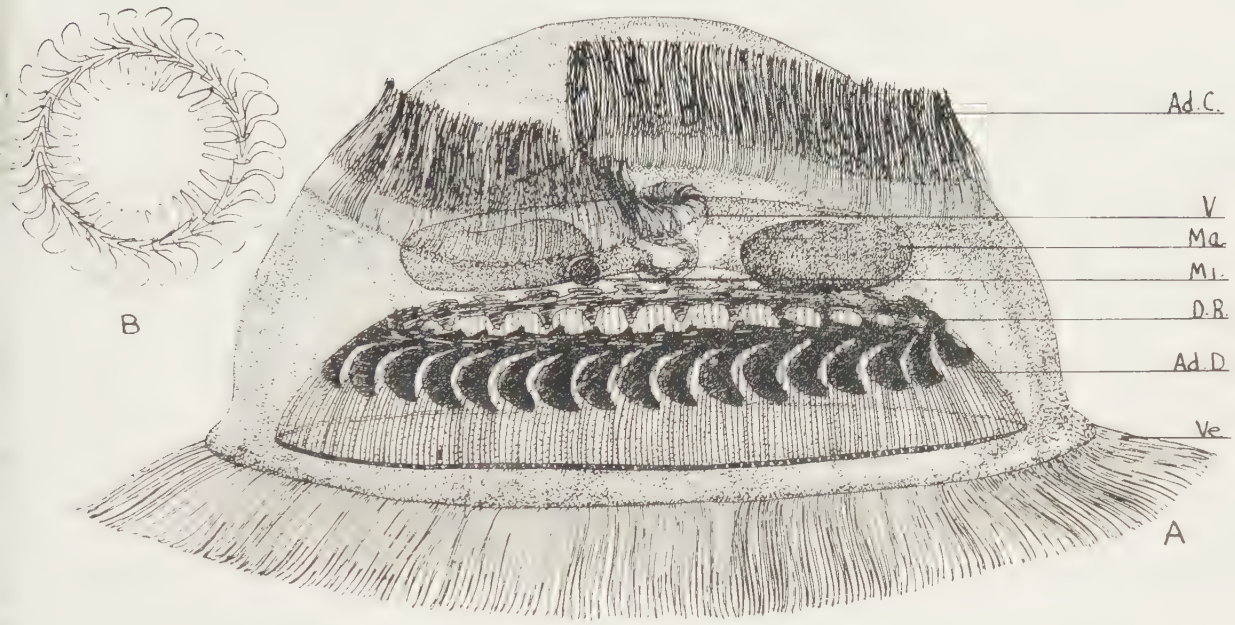
shaped, with comparatively few basophilic granules; it lies in the posterior half of the cell, parallel to the dorsal plane of the adhesive disc; the open ends of the macronucleus extend to the oral side and surround the descending portion of the gullet. Contractile vacuole lies close to the descending portion of the vestibulum and during trophic life, fission and post-conjugative reorganization, it is found in the posterior half of the cell. Trophic micronucleus small, lies close to the left tip of the macronucleus; during conjugation its position is variable.

Remarks: Many individuals of this species were found to be infected with the suctorian parasite, *Endosphaera engelmanni*. In such cases, position of the nuclei and other cytoplasmic contents may be greatly displaced. The above description is based on several hundred normal ciliates. *Trichodina spheroidesi* is distinguished from other *Trichodina* described from marine fishes by the presence of the inner ring of aboral cilia.

Trichodina halli sp. nov.

(Text-fig. 2).

Description: Hemisphere or dome-shaped organisms. Diameter, taken at the base,



Text-fig. 2. **A.** *Trichodina halli.* Side view. × 950. Semi-diagrammatic reconstruction from hematoxylin and silver nitrate preparations. Legend same as in Text-fig. 1. Note the absence of inner aboral ring of cilia. **B.** Denticulate ring. × 475.

ranges from 45–86 μ. Adoral cilia present, similar in arrangement and extent to *T. spheroidesi.* Only one ring of aboral cilia evident: membranelle absent. Disc diameter varies from 41–81 μ; striae present in two layers. Denticulate ring thicker than in *T. spheroidesi;* diameter ranging from 30–54 μ; denticles fitted together by the insertion of a cone-shaped protuberance of one denticle into a corresponding depression in adjacent one (Text-fig. 2, B). Number of hooks varies from 26–34; hooks shaped and curved like a ship's propellor blade and joined to the denticles at an angle so that when observed on edge the broad area is not evident and they appear to be crescent shaped. Macronucleus as in *T. spheroidesi,* except that arms are longer and there are more basophilic granules present. Position of the micronucleus and other structures typical.

Remarks: *Trichodina halli* can be distinguished from *T. spheroidesi* in the following ways: (1) size of organism and organelles considerably larger, (2) ratio of disc diameter to the diameter of the organism as a whole is less, (3) denticulate ring thicker, (4) shape and arrangement of denticles and hooks entirely different, (5) longer arms of the macronucleus, and (6) lack of inner ring of aboral cilia.

The variation in size of both *T. spheroidesi* and *T. halli* suggests that other species of *Trichodina* reported in recent years may have presented a like variation in range of measurement if sufficient numbers were studied. A review of the reported species shows that in very few instances was this range adequately determined. In the table below a comparison of measurements of various structures of *T. spheroidesi* and *T. halli* with the available data of some previously reported marine species is made. As may be seen from this table all the species, except *T. halli,* fall within the size range of *T. spheroidesi.* The distinguishing features of most of these forms consist mainly in host specificity (?) and minor variations as to shape, ciliary pattern, nature of adhesive disc and denticulate ring. Since such information is not given in sufficient detail these organisms cannot be keyed out.

TABLE I.

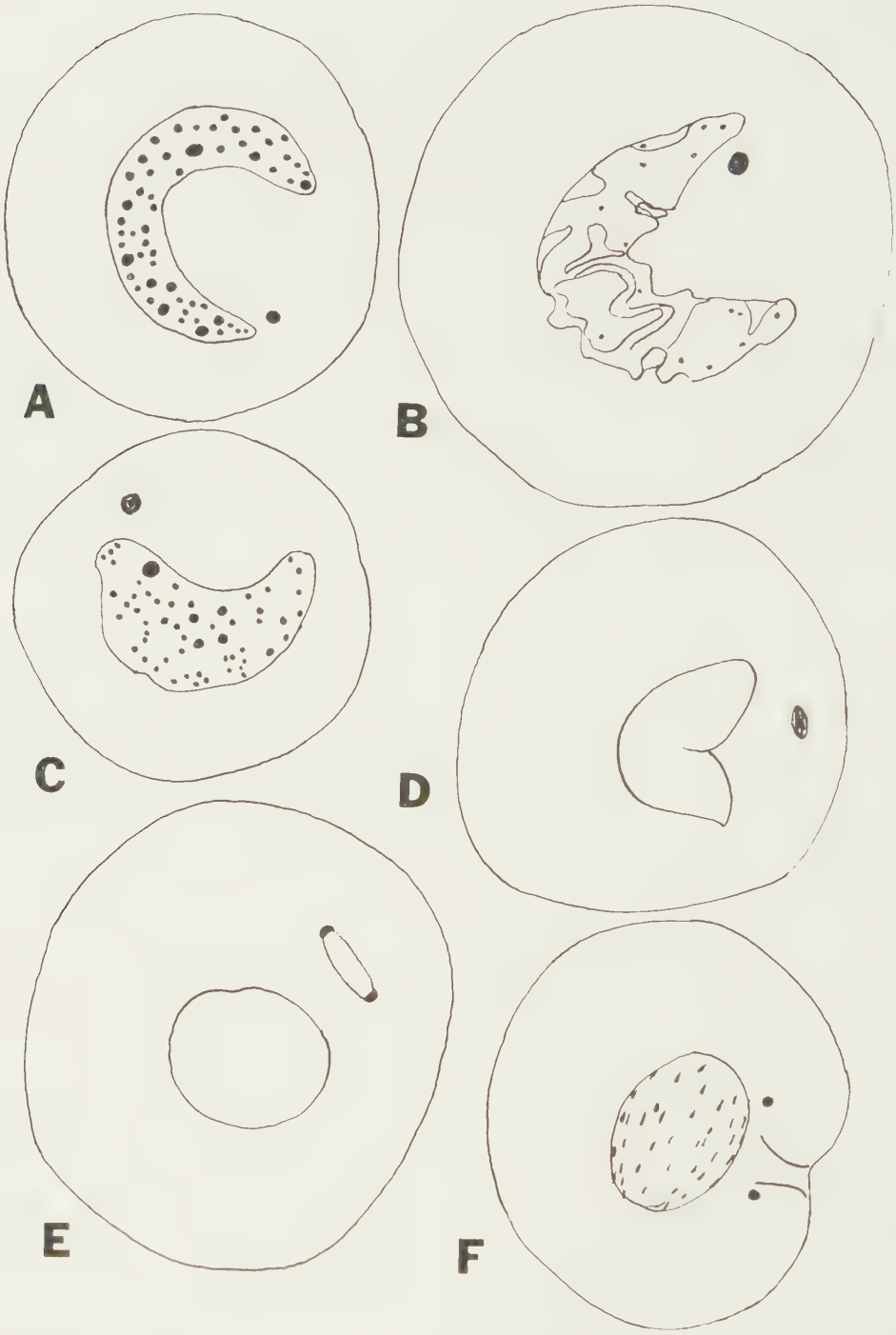
Measurements (in mm.) for *Trichodina* from Marine Fishes.

Species	Height	Width	Disc Dia.	Ring Dia.	Hook No.
blenni	20–32	40–45	24–27		24–32
lini	20	37	20		24
helidonichthys	19–27	30–45	19–32		30
mustis	14–20	33–44	23–28		32
fariai	32	40		20–42	24–28
T. labrorum	18–22	30–34			21
T. spheroidesi	12–42	17–54	18–32	14–22	21–31
T. halli		45–86	41–81	30–54	26–34

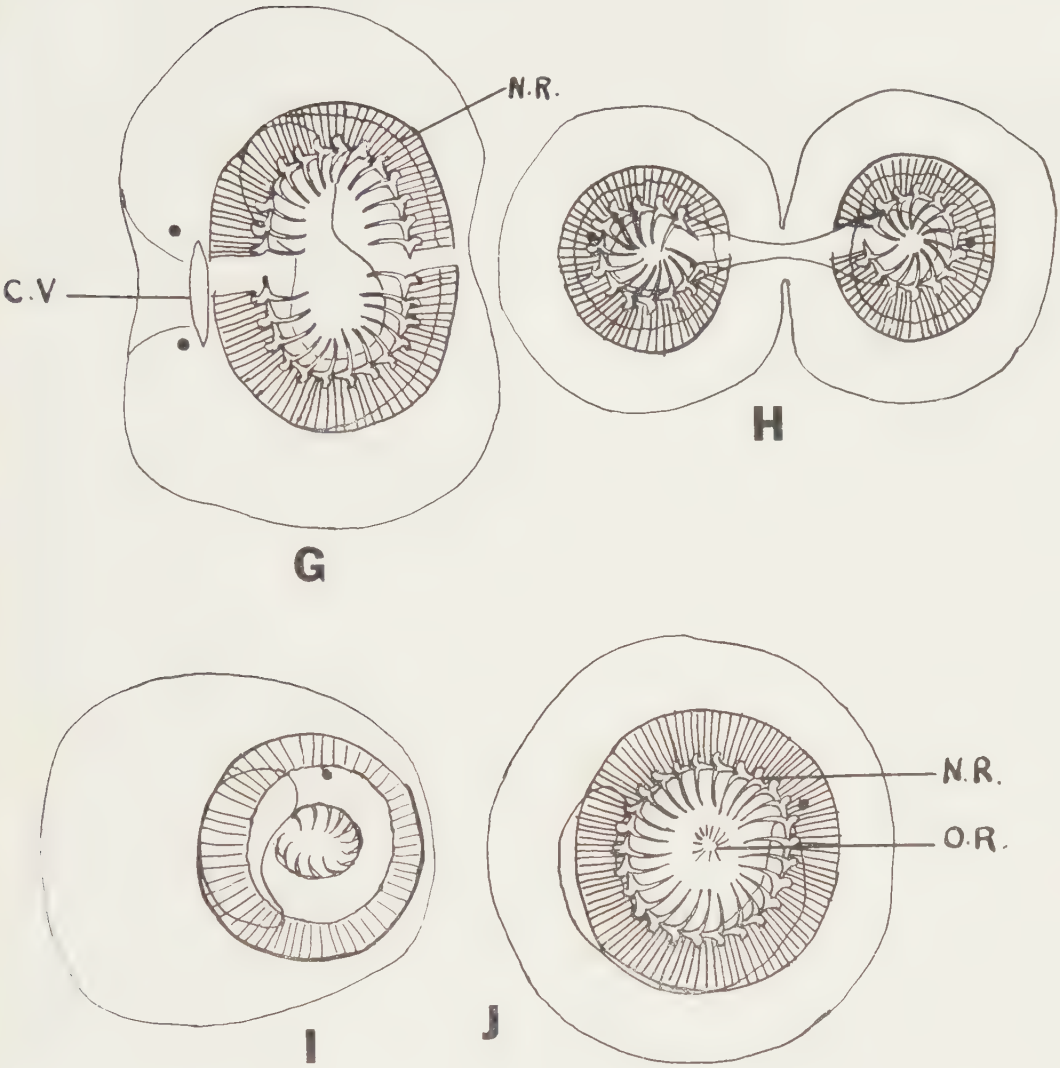
Binary Fission in *Trichodina spheroidesi.*

(Text-figs. 3 & 4).

The stages of fission in *T. spheroidesi* correspond very closely to those described by Diller (1928) for the species of *Tricho-*



Text-fig. 3. Binary fission in *Trichodina spheroidesi*. × 950. From iron-hematoxylin preparations. **A**, trophic stage; **B**, macronucleus in stage of contraction; **C**, **D**, and **E**, further contraction of the macronucleus; **B** and **C**, note swelling of micronucleus; **D**, micronucleus in metaphase; **E**, telophase; **F**, completed micronuclear division.



Text-fig. 4. *Trichodina spheroidesi.* × 950. Iron-hematoxylin preparations. **G, H, I, J,** binary fission stages showing the final division of the macronucleus and the reorganization of the denticulate ring. **C. V.,** contractile vacuole; **N. R.,** new ring; **O. R.,** old ring.

dina from tadpoles. The trophomacronucleus undergoes vacuolization and clefts appear in the ground substance (Text-fig. 3, B). The macronucleus begins to condense while the chromatin granules, large in the trophic stage, become smaller in size and randomly distributed in the matrix. As the macronucleus contracts further, the micronucleus swells, eventually becoming spheroidal, then divides mitotically (Text-fig. 3, C, D, E). A metaphase stage of a dividing micronucleus is shown in Text-fig. 3 D. The mitotic division continues as the macronucleus pulls apart, and two daughter micronuclei are formed before the macronucleus is completely divided (Text-fig. 3, F; Text-fig. 4, G).

Plasmotomy takes place about the time of the late telophase. A stricture appears in the ventral portion of the organism, and the adhesive disc and denticulate ring separate into approximately equal halves (Text-fig. 4, G, H). Final cleavage of the macronucleus takes place and two daughter cells are formed (Text-fig. 4, H).

Peshkowsky (1923) reported that during division of *Trichodina steinii* and *T. mitra* the adoral cilia, gullet and contractile vacuole are absorbed. Careful study of the silver impregnated material, however, leads the

writers to believe that the adoral and the aboral zones of cilia, in *T. spheroidesi* at least, are retained throughout division. The fate of the vestibulum and the vestibular cilia could not be traced. In specimens stained with hematoxylin, it was observed that the contractile vacuole is retained also during cell division. It appears to cleave concomitantly with the cleavage of the macronucleus (Text-fig. 4, G).

The anlage of the new denticulate ring (corona) is laid down as a delicate ring close to the posterior border of the adhesive disc before the onset of cell division (Text-fig. 4, G). This confirms the observations of Diller (1928). After the formation of the daughter cells the new corona gradually develops its denticles and hooks and takes up a more dorsal position on the adhesive disc. The rays are the last structure to be formed in the ring. Half of the old ring, carried over after cell division by each daughter cell, is pushed into the ventral plug of the cytoplasm between the aperture of the adhesive disc. Here it is slowly resorbed (Text-fig. 4, I, J).

Conjugation in *Trichodina spheroidesi*. (Pl. I–III).

Conjugation in *T. spheroidesi* is anisogamous and the process is very similar to that reported by Maupas (1888) for *Vorticella nebulifera* (see also Doflein, 1927). The aboral surface of the microconjugant is fitted over the adoral surface of the macroconjugant (Pls. I, II). They may or may not be oriented in the same direction. After the conjugants have assumed their respective positions, the micronucleus of each begins to swell, eventually becomes vesicular and passes from the original posterior position to a more central location in the cell (Pl. I, Figs. 1–3). The macronucleus begins to show signs of vacuolization (Pl. I, Fig. 2).

At the time of spindle formation, the macronucleus twists and pulls apart into large coarse fragments (Pl. I, Fig. 3). These pieces continue to break up into smaller and smaller parts until minute spherical bodies with deeply staining granules are formed (Pl. I, Figs. 4, 5, 6, 7, 8; Pl. II, Fig. 9).

Micronuclear activity immediately preceding the metaphase period is not clearly defined (Pl. I, Fig. 4). It is possible that the micronuclei have a decreased affinity for iron-hematoxylin stain during these stages. The metaphase spindle, however, is clear and granular chromosomes can be identified about the center (Pl. I, Fig. 5). During the final fragmentation of the macronucleus, two micronuclear divisions take place in each conjugant (Pl. II, Fig. 10).

It is of interest to point out here that conjugation in *T. spheroidesi* differs from conjugation in *Vorticella nebulifera* in that there are only two micronuclear divisions in each conjugant instead of three.

Protoplasmic continuity is established between the conjugating individuals (Pl. II, Fig. 11), and the contents from the smaller individual pass into the larger one (Pl. II, Fig. 12). It is assumed that the gametic nuclei (Pl. II, Fig. 10) then combine to form the synkaryon, and the remaining nuclei are resorbed. The remains of the microconjugant collapse and the ensuing processes of conjugation are confined to the single large exconjugant (Pl. II, Fig. 13).

At the onset of its first division, the zygotic nucleus develops a larger spindle than any of the dividing nuclei in the early stages of conjugation. It is assumed that three mitotic divisions subsequently occur, resulting in eight micronuclei. Seven of these become the macronuclear anlage and one the functional micronucleus (Pl. II, Figs. 14, 15). The functional micronucleus divides (Pl. II, Fig. 15) and in the cell division which takes place, the macronuclear anlage are distributed between the daughter individuals (Pl. III). The most frequent distribution is three and four (Pl. III, Figs. 16, 17). However, the distribution may sometimes be two and five (Pl. III, Figs. 18, 19) or one and six. Cell division continues until each of the daughter cells formed contain one macronuclear anlage (Pl. III, Fig. 20). The macronucleus then increases in size and develops its characteristic horse-shoe shape.

Reorganization of the denticulate ring occurs in the macroconjugant shortly after the fusion of the protoplasmic contents of the conjugants has occurred. Figures 12 and 13 of Plate II show the newly formed ring together with the remains of the old denticulate ring. It should be pointed out that the original ring is present in preceding stages but is not shown in the figures for sake of clarity. It is of interest to note that the number of denticles in the new ring is invariably the same as the number present in the old ring. Such structures as the gullet, vacuole and cilia are present throughout conjugation.

Discussion.

Trichodina spheroidesi is distinguished from other *Trichodina* of marine fishes by the presence of the inner ring of aboral cilia. Wetzel (1927) and Precht (1935) reported a similar observation for *T. pediculus* and *T. scoploplontis*, respectively.

The double layer of striae in the adhesive disc observed by the writers in the two forms from the puffers have been previously reported by Mueller (1932, 1938) for *Trichodina renicola* and *Vauchomia nephritica*. Mueller (1938) refers to the inner group of striae as the posterior hard rays and the outer group as the anterior soft

rays. He further commented that the soft rays comprise a system of myonemes which connect with the posterior girdle of cilia. This duplex nature of the striae Mueller featured to distinguish members of the Trichodinidae found in the urinary tract of fishes (e.g., *T. renicola* and *V. nephritica* from *Esox niger* and *Esox masquinongy*, respectively) from those found on the gills of certain fresh-water fishes reported by him in 1937. In the ciliates from the gills only the hard rays were present in the striated ring. However, the occurrence of double striations in the forms described by the writers suggests that this feature may be more widespread than heretofore has been observed.

The similarity of conjugation in *Trichodina pediculus* to that of certain members of the Vorticellidae was first pointed out by Busch (1855). Stages in conjugation among certain of the Urceolariidae have since been recorded and the same comparison made. Caullery & Mesnil (1915) reported stages in conjugation in *Trichodina patellae* (Cuenot) from a species of fresh-water mollusc. Peshkowsky (1923) described conjugation in *T. steinii* and commented that this process was similar in all essential features to that observed in the Vorticellidae. Anisogamous conjugation was described by Zich (1928) for *Urceolaria korschelti*, and by Hunter (1936) for two types of *Trichodina* found in the intestine of sea-cucumbers. Diller (1928) described in detail endomixis in *Trichodina* from tadpoles. He suggested that some of the evidence of conjugation presented by Caullery & Mesnil, Peshkowsky and others were most likely stages in endomixis. The endomictic stages described by Diller, however, conform closely to the nuclear reorganization in the post-conjugative stages described for *Trichodina spheroidesi*. Diller makes a distinction between endomictic individuals and conjugating forms on the basis of differences in shape of macronuclear fragments. Since the fragments in Diller's material are not unlike those observed in some of the stages in conjugation in *T. spheroidesi* this distinction cannot be supported. Any other differences that Diller may have noted are, in all probability, the result of examining too few samples of conjugation which he stated was present in his material. That he may have misinterpreted post-conjugation for endomixis is supported further by the similarity of his figure (Pl. II, Fig. 14) of the first micronuclear division to the figure of the zygote nucleus in *Vorticella nebulifera* shown by Maupas (1888) (see Doflein, Fig. 310) and in *Trichodina spheroidesi* (Pl. II, Fig. 13).

Summary.

1. *Trichodina spheroidesi* and *T. halli* spp. nov. from the gills and skin of puffers (*Spheroides maculatus*) and other marine fishes from the New Jersey and the New York coast are described.

2. The processes of fission and conjugation are described for *T. spheroidesi*.

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EXPLANATION OF THE PLATES.

Anisogamous conjugation in *Trichodina spheroidesi.* All figures drawn from material stained with iron-hematoxylin. × 950.

PLATE I.

Fig. 1. Start of conjugation.

Fig. 2. Macronucleus in the process of fragmentation. Note lumping of nuclear material. Micronucleus in pre-metaphase stages of meiosis.

Fig. 3. First macronuclear fragmentation. Micronucleus still in pre-metaphase stage.

Fig. 4. Further macronuclear fragmentation.

Fig. 5. Metaphase of meiotic nucleus clearly evident. Fragmentation of the macronucleus continues.

Figs. 6, 7, 8. Continued meiotic division and completion of fragmentation of the macronucleus into many spherical and oval shaped bodies of various size.

PLATE II.

Fig. 9. Continuance of the meiotic process seen in Fig. 8.

Fig. 10. Second micronuclear division. Note persistent gametic micronucleus and the degeneration of other three micronuclei in each conjugant.

Fig. 11. Gametic nuclei in an early stage of fusion to give rise to the synkaryon. The other micronuclei completely disappeared. Note the completion of cytoplasmic continuity between the conjugants.

Fig. 12. The cytoplasmic contents of the microconjugant pass into the macroconjugant. The new denticulate ring develops while the old ring is resorbed. In this individual the macronuclear fragments are coarser than in the preceding stage.

Fig. 13. Post-conjugant stage. Macroconjugant with large zygotic nucleus in metaphase stage. New denticulate ring and remnant of the old ring still present.

Fig. 14. Initial stage in development of the macronuclear anlage. There are seven of these larger bodies present, indicating that three divisions of the zygotic nucleus had taken place.

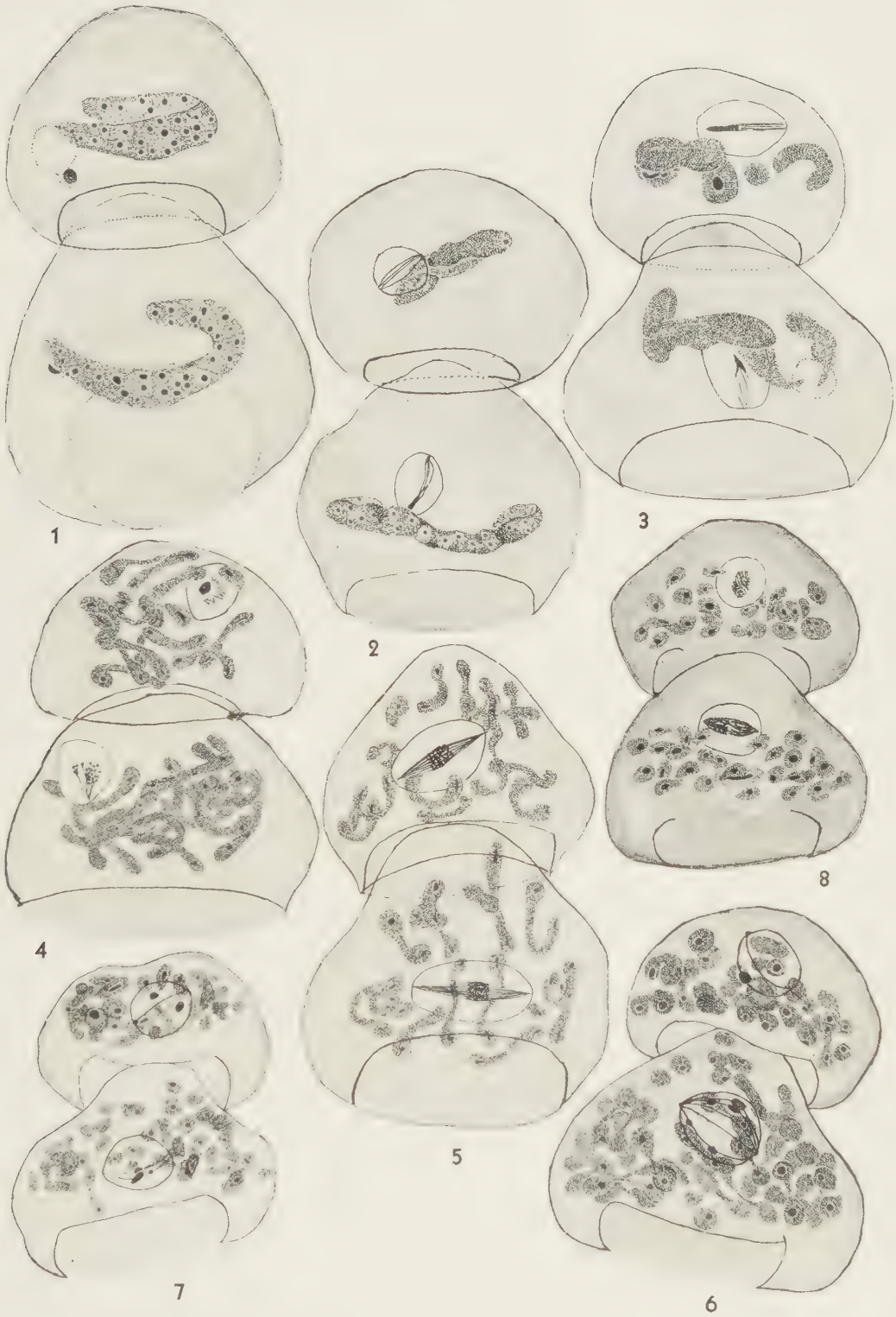
Fig. 15. Further development of the macronuclear anlage. The start of the first binary fission. Micronucleus in metaphase.

PLATE III.

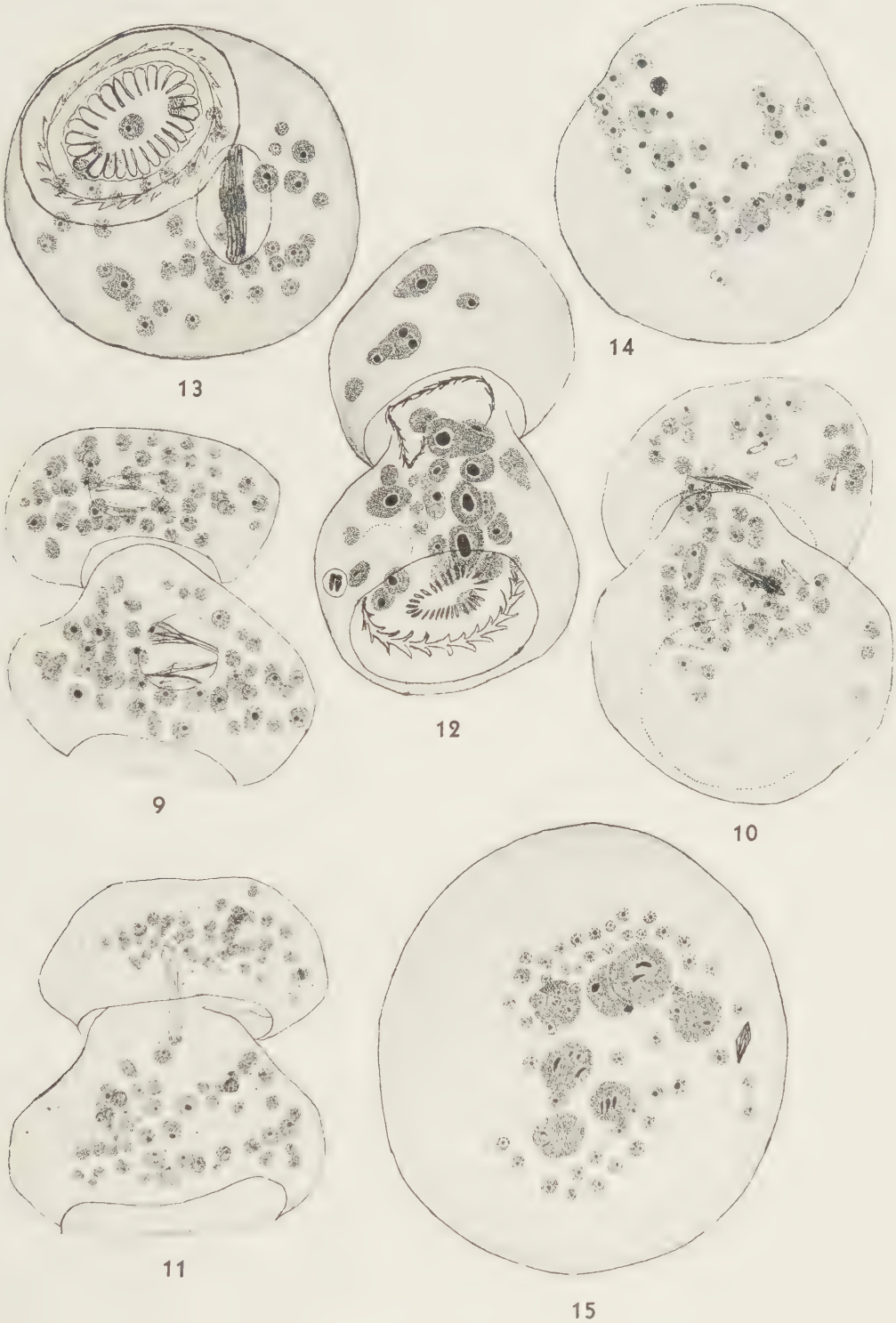
Figs. 16, 17. Daughter cells showing the three and four macronuclear anlage distribution.

Figs. 18, 19. A two and five distribution of macronuclear material.

Fig. 20. Each cell will continue to divide until only a single macronuclear anlage is present in each individual. The last step in this process is shown in this figure.



TRICHODINA SPHEROIDESI AND TRICHODINA HALLI SPP. NOV. PARASITIC ON THE GILLS AND SKIN OF MARINE FISHES, WITH SPECIAL REFERENCE TO THE LIFE-HISTORY OF T. SPHEROIDESI.



TRICHODINA SPHEROIDESI AND TRICHODINA HALLI SPP. NOV. PARASITIC ON THE GILLS AND SKIN OF MARINE FISHES, WITH SPECIAL REFERENCE TO THE LIFE-HISTORY OF T. SPHEROIDESI.

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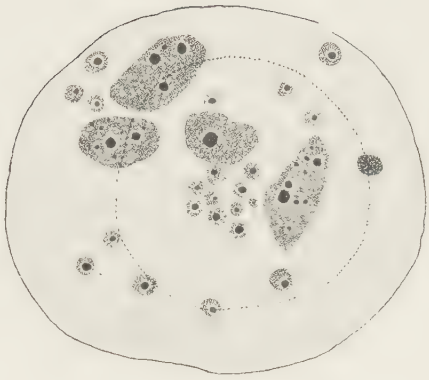

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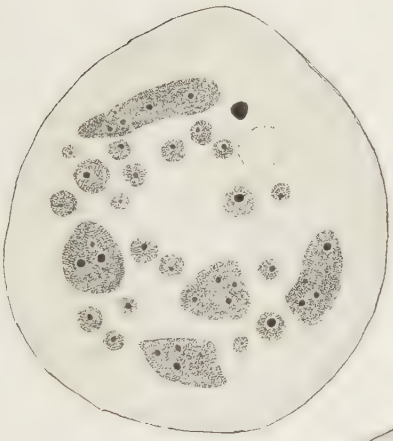

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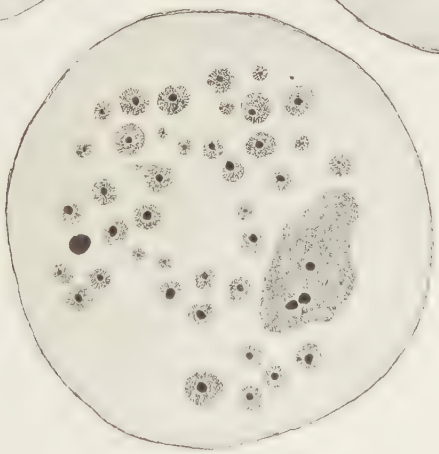

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TRICHODINA SPHEROIDESI AND TRICHODINA HALLI SPP. NOV. PARASITIC ON THE GILLS AND SKIN OF MARINE FISHES, WITH SPECIAL REFERENCE TO THE LIFE-HISTORY OF T. SPHEROIDESI.

13.

Mortality of Albino Embryos and Aberrant Mendelian Ratios in Certain Broods of *Xiphophorus hellerii*.[1]

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(Text-figure 1).

In a previous publication,[2] the author has shown that when the albino swordtail is mated with the golden variety, their offspring resemble neither parent but revert to the ancestral gray coloration of the wild species.

The author showed further that when the gray offspring of the above mating reached maturity and were mated together, brother to sister, the second generation population consisted of three color classes: 202 were "wild" gray, 65 were golden and 67 were albino. These frequencies approached the theoretical 9:3:4 ratio and were interpreted on the basis of the recombination of two independent autosomal factors: *St I* for "wild" gray, *st I* for golden and *St i* and *st i* for albino.

To get the above data the results of four matings were pooled, as Table I will show.

TABLE I.

Second Generation Offspring of Gray (*Stst Ii*) Swordtails.

Female No.	Gray	Golden	Albino
70–4	37	12	8
70–5	38	13	6
70–6	50	15	20
70–7	77	25	33
Totals observed	202	65	67
expected	188	63	83

It was noted that there was a deficiency of albinos in the above totals, particularly in broods from females 70–4 and 70–5, yet the two independent factor hypothesis seemed most appropriate in explaining the results. This was confirmed when the Chi-Square test for significance was applied to the pooled data; the value of Chi-Square was found to be 4.18. However the value of Chi-Square for the first two broods alone was 9.84 and indicates the deviations found here cannot be attributed to chance.

Broods were obtained from three additional females after mating with their gray brothers. The three females, 70–8, 70–9 and 70–10, yielded ratios so obviously aberrant that counts of their young were not included in the original presentation because it was thought, at the time, that a contaminating factor was involved in this portion of the experiment. Further study was undertaken to account for these unusual results.

Reports from the laboratories of other workers and from our results as indicated in Table I pointed to a deficiency of albinos in genetic tests. This was attributed to the constitutional weakness of the albino individuals. It was noted, for instance, that if the fishes of a brood are counted soon after birth and again after two months, the death rate of albinos is greater than that of the other color varieties.

From this evidence it was suspected that the weakness of the albinos may be manifest early, perhaps in their embryonic stages of development. The three additional females, 70–8, 70–9 and 70–10, that produced hardly any albinos in their first broods (see Table II), were killed three weeks after giving birth to their last brood. The females were dissected, their embryos were removed and counts were made of them. In each case an appropriate proportion of albinos was found among the gray and golden embryos. This may be seen in Table II.

DISCUSSION AND CONCLUSIONS.

It is obvious that the numbers of albinos are decidedly deficient among the young fishes from females 70–8, 70–9 and 70–10; the extremely high value of Chi-Square, 42.46, indicates that the results obtained are not due to chance variation alone. On the other hand, the numbers of albinos

[1] I wish to express my thanks to the Department of Birds of the American Museum of Natural History for the use of their laboratory in the Whitney Wing of the Museum.

[2] Back to their Ancestors, *Journal of Heredity*, 32: 385-390, 1941.

9 "Wild" Gray 3 Golden 4 Albino

Text-fig. 1. Embryos from gray females mated to gray males.

TABLE II.

Offspring of Gray (*Stst Ii*) Swordtails.

Female No.	Gray	Golden	Albino	
70–8	38	11	2	Young
	35	10	13	Embryos
70–9	45	10	1	Young
	40	9	12	Embryos
70–10	58	18	1	Young
	40	12	17	Embryos
Totals:				
Observed	141	39	4	Young
Expected	103.5	34.5	46	
Observed	115	31	42	Embryos
Expected	106	35	47	

found among the embryos of the same females are in close harmony with expectancy. The slight deviations found may be attributed to chance, for the Chi-Square value is low, 1.75.

In light of all the data, the gray females tested may be divided into three groups according to their ability to produce viable albino swordtails. Females 70–8, 70–9 and 70–10 fail in this respect almost completely; females 70–4 and 70–5 fail to produce an adequate number according to expectancy; females 70–6 and 70–7 have the ability to produce viable albino young in normal numbers.

Thus the deficiency of albinos in certain broods must be attributed not only to the low viability of the albinos themselves but also to some failure in the ability of the albinos' mothers to carry their complete broods through to birth.

14.

The Schooling Behavior of Mackerel: A Preliminary Experimental Analysis.

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(Plate I).

INTRODUCTION.

As indicated in the comprehensive review of the field by Allee (1931), animal aggregations and their significance have attracted increasing critical analysis in recent years. Curiously, the fish school—one of the most striking examples of well-integrated animal aggregations — has received remarkably meager critical attention. Spooner (1931) and Breder & Nigrelli (1935), considering various aspects of schooling in fishes, have noted this unfortunate lack of literature. Some notes on the schooling behavior of the herring, *Clupea harengus* L., by Newman (1876), constitute one of the earliest publications in this field. Nevertheless, Parr (1927) after a fifty year interval had a virtually clear field for his theoretical analysis of the schooling behavior of mackerel.

Fishes which do not school and have no visible aggregating tendency have been considered "non-social" forms. However, it is unwise to so classify a form which manifests no obvious social tendencies. Statistical evidence has demonstrated that the goldfish, which had been summarily thus dismissed, manifested a definite group effect; isolated individuals were found to have a higher rate of locomotor activity and oxygen consumption than did grouped goldfishes (Schuett, 1934; Escobar, Minahan & Shaw, 1936; Breder & Nigrelli, 1938; Shlaifer, 1938). Hence, social tendencies may be relatively obscure and not readily determined by casual observation.

At the extremes, it is a relatively simple matter to differentiate between a loosely aggregating fish and a closely schooling one. However, in many cases it is exceedingly difficult to determine whether a fish should be considered a closely aggregating form or a loosely schooling one. The mackerel imposes no such difficulties. It remains in dense schools throughout life, except for possible dispersal at night. It is difficult to think of an instance, at least among vertebrates, in which individuality is as completely lost as it is in a mackerel or herring school.

Parr (1927) subjected the mackerel school to critical theoretical analysis. Several interesting conclusions were reached which will be considered later. His report, however, contains relatively little experimental data. It is the purpose of this report to treat the phenomenon experimentally and, wherever possible, to attempt correlation with Parr's theoretical conclusions.

The writer wishes to express his deep appreciation to the U. S. Fish and Wildlife Service at whose Woods Hole station the experiments were performed; also to Dr. R. Buchsbaum whose photographic skill is responsible for the figures in the plate.

EXPERIMENTAL STUDY.

Number of Individuals Needed to Form a School: The experimental animals used in these and subsequent tests were 8-inch specimens of the chub mackerel, *Pneumatophorus grex* (Mitchill). Originally caught in the waters off Woods Hole, they were subsequently kept in appropriately large tanks in the laboratory. Several days were allowed for acclimatization before the animals were used. Two tanks were employed for experimental purposes. One was a rectangular assembled aquarium with transparent glass sides whose dimensions were 36″ by 15″ and 17″ deep. The other was a rectangular wooden tank 44″ by 23″ and 9.5″ deep. Sea water was kept running through these tanks at all times at a fairly rapid rate. The average oxygen content was 5.60 cc. per liter and the temperature range was 18–20 degrees C. In general, the mackerel survived well. Of those that died, many expired during the course of acclimatization in the laboratory. Most of those which survived this period lived for several weeks in no apparent distress.

Repeated experiments demonstrate that

two individuals suffice to form a mackerel school. If two fishes are removed from a group and placed in the wooden tank they immediately school, i.e., swim about the tank nearly always in line with each other. If one mackerel is kept isolated in a tank and another is grouped with it, they immediately school. Apparently, the fish that first becomes aware of the presence of the other initiates the schooling reaction. Whether this will be the original fish or the introduced one is purely a matter of chance for it will be one or the other 50% of the time. Other fishes added to this group of two immediately join the school.

Thus, only two individuals are required to begin the formation of a mackerel school which is, however, better integrated if composed of many individuals.

Breder & Nigrelli (1935) found that two sunfishes, *Lepomis auritus*, grouped together in a tank "aggregate" with each other after two days. Shlaifer (1938) demonstrated that the oxygen consumption and locomotor activity of an isolated goldfish is significantly higher than is that of an individual in a group of two.

It would seem, at least in the cases listed above, that there is a much greater psychic difference between an isolated fish and one in a group of two than between the latter and an individual in a much larger group.

Effect of Various Types of Blinding: Parr (1927) found that when chub mackerel were blinded by the application of vaseline and lampblack to the eye, they did not school or mill. Blinded catfishes do not aggregate (Bowen, 1931) nor do blinded sunfishes (Breder & Nigrelli, 1935). Grouped goldfishes which are normally less active than isolated individuals lose this group effect when they are blinded (Shlaifer, 1939). These results as well as other lines of evidence indicate the importance of vision in integrating social behavior in fishes.

The experiments described below were designed to repeat and to extend the original work of Parr (1927) on this species. Mackerel were blinded by piercing the cornea and were kept in the wooden tank described above. One day was allowed for recovery from operative shock. Blindness was ascertained by appropriate tests, e.g., failure to avoid a net, etc. All results noted for the various blinding experiments were confirmed by repeated tests. As controls, the area in the vicinity of the eye of nonblinded mackerel was pierced by the same instrument used for blinding, thus approximating similar conditions of shock. In no case did control individuals fail to school when grouped.

If an individual is blinded on one eye and subsequently grouped with six schooling mackerel, it immediately joins the school. In fact, if only three minutes are allowed for recovery from the shock of the operation instead of the customary day, it also rejoins the school immediately. This half-blinded fish succeeds in maintaining its orientation with respect to the rest of the school fairly well. Sudden turns by the normal animals to the blinded side of the experimental fish may result in temporary loss of integration of that animal with the school; however, it is quickly recovered.

If a mackerel is subjected to bilateral blinding, it makes no attempt to join the school. Occasionally its random movements about the tank may disrupt the smooth integration of the normal school but only for a moment.

The grouping of a normal fish with a half-blinded one results in a schooling reaction. In general, the unilaterally blinded animal will orient itself so that the intact eye side is the one nearest the normal fish. Sudden turns by either animal will initiate a turn in the other, thus maintaining the school. If the half-blinded fish is then blinded on the other eye, the school disintegrates. There is, of course, no reaction by the sightless form to the normal one. However, it might be expected, inasmuch as there is no other mackerel in the tank but the blinded individual, that the normal fish would attempt to school with it. This is not the case.

Sightless mackerel do not swim in a typically normal manner; movement is slower and less uniform. Apparently, normal swimming movement is of great importance in the schooling reaction of mackerel.

If two mackerel are blinded on the same eye, a school obtains though it is not as well integrated as is a school of two normal individuals or one normal and one half-blinded form. In this case the maintenance of the school is dependent upon the behavior of the fish whose intact eye side is nearest the other animal whose swimming movement is apparently sufficiently normal to evoke a schooling reaction by the mackerel which is in visual contact with it. We are presented with the unusual case of a school of two fishes, one of which plays a passive role. Sudden turns and changes in direction may reverse the role of either fish. The mackerel which sees the other member of the group of two usually follows the turns of the passive partner. On occasion, however, it may initiate a turn, in which case the school is broken for a second or so until one individual finds the other.

If, in a group of two, one mackerel is blinded on its left eye and the other on its right one, schooling behavior is very erratic. If their blinded sides face each other no reaction obtains; if not, they school, though the school is likely to be broken by a sudden sharp turn by one animal which results in

their blinded sides facing each other again.

A totally blinded fish grouped with a half-blinded one evokes no good schooling reaction by virtue of the abnormal movement of the former. Two totally blinded individuals grouped together will swim at random and may collide.

Confirming Parr's data (1927), three mackerel blinded in both eyes and placed in an exhibition tank containing a large school of mackerel swim aimlessly and make no attempt to join the group.

The results obtained demonstrate the role of vision. Also indicated is the importance of normal swimming movement.

Any experiment in which visual response is eliminated through blinding suffers from the criticism that the normal physiological state of the animal may be disturbed. This may be true even when a period deemed to be sufficient for recovery from shock obtains. A more natural condition is darkness and a description of the behavior of mackerel in this state follows.

The Effect of Darkness on Schooling: Newman (1876) finds that the closely schooling herring, *Clupea harengus*, break up completely at night in a tank in captivity, each fish taking an independent path. The school reforms in the presence of sufficient light. Breder (1929) reports that compact schools of *Jenkinsia*, also a member of the family Clupeidae, are dispersed at night. Bowen (1931) finds that aggregations of catfishes are dispersed in darkness. Breder & Nigrelli (1935) report that aggregations of the sunfish, *Lepomis auritus*, break up with the coming of night. Shlaifer (1939) finds that the effect of grouping (decreased oxygen consumption) on goldfishes disappears in total darkness.

The behavior of mackerel in darkness was investigated by two procedures, one observational, the other photographic. One of the exhibition tanks of the Aquarium at the Woods Hole station of the U. S. Fish and Wildlife Service contains a school of forty to fifty 8-inch chub mackerel, as well as a turtle, flounder, blackfish, and skate. The tank, rectangular in shape, is 6.5 feet by 4 feet and 3 feet deep. Three of the vertical sides are composed of stone and cement and the fourth of transparent glass.

The lights in the Aquarium were always off at night and after 9 p.m. the room was quite dark. The observer, looking at the tank from above or standing next to the transparent glass side, could see nothing in the tank; in fact, one's hand held two inches from the eye was quite invisible. For several hours at night during several consecutive evenings observations were made on the schooling behavior of the mackerel in this state of darkness. At half-hour intervals a flashlight beam was directed at the bottom of the exhibition tank for only one or two seconds. If maintained longer, the fishes would react to the light, weak though it was, by forming a dense school. Hence, it was necessary to form an impression of the aggregating condition of the group in this very short time. The general impression gathered by these observations was that the school was fairly well dispersed. The fishes were never found to be closely schooling or milling but neither were they swimming about the tank at random as Newman (1876) reported for the herring in darkness. The mackerel swam in an elliptical orbit more or less in the same direction but with considerably greater distances between individuals than is found in a normal school in the light. Considering the number of individuals, the size of the tank, and the tendency of mackerel to swim in a uniform way for hours unless disturbed, the observed state of the school is probably what is to be expected in the absence of visual integration. Further experiments are planned along these lines.

The mackerel eye is apparently capable of detecting similarly moving forms at very low light intensities for when they could just barely be seen they were in fairly compact schools. This is in contrast to the findings of Breder & Nigrelli (1935) for sunfish aggregations which break up when they can still be seen distinctly. Another interesting fact is that the mackerel also is capable, apparently, of seeing in light at the deep red end of the spectrum. When a Wratten Series II Safelight, which transmits light in the deep red from about 650μμ. to 700μμ., was suspended at night over the tank several inches from the water surface in otherwise total darkness, the mackerel formed fairly compact schools and mills. (See Plate I, Fig. 3.)

The observational method described above is open to the criticism that the observer's reaction must be instantaneous and is subjective. Accordingly, a series of flash-bulb photographs was made of the mackerel group in artificial light and in total darkness. These flash-bulb photographs are taken in a fraction of a second, much too fast for any disturbance caused by the blinding flash of light to be recorded in the photograph. The school was photographed from the side through the transparent glass. Darkness shots were taken only after a period of at least 15 consecutive minutes of darkness following the small amount of illumination from a flashlight incident to setting up the equipment. Darkness set in at about 9 p.m. and the first photograph was usually taken at about 10 p.m. Plate I contains two photographs which represent typical results. Fig. 1 is a compact mackerel school under fairly strong artificial light. Fig. 2 was taken in total darkness at about 10:30 p.m. The contrast in the denseness of the aggregations

is obvious and portrays the results obtained by observation.

The observational and photographic evidence reveals that mackerel schools apparently are dispersed in total darkness. However, the ability of mackerel in aquarium tanks to school at very low light intensities leaves unsolved the condition of mackerel schools in nature where dim light may obtain at night. It is the intention of the writer to pursue this matter more exhaustively in future work.

Visual Contact: Shlaifer (1939, 1940) found that the oxygen consumption and locomotor activity of isolated goldfishes in visual contact with others of the same species and variety was of the same order of magnitude as that of these individuals when actually members of a group. This confirmed previous results which demonstrated the visual integration of the group effect. Although darkness and blindness tests have indicated the importance of vision in the schooling behavior of mackerel, the following experiment was performed as a bit of additional evidence.

The glass tank whose dimensions have been listed above was divided in half along its length by a plate of transparent glass. One mackerel was placed on each side. After a short period of acclimatization, the two fishes tended to swim close to the dividing glass plate in line with each other. In general, the animals would turn only when they reached one end of the tank and would then swim back to the other end. If, however, one mackerel turned in the center of the tank, the fish on the other side of the glass in visual contact with it would usually also turn before reaching the end of the tank. This behavior was not invariable but occurred with sufficient frequency to be considered significant.

Thus, from three lines of evidence—blinding, darkness, and visual contact experiments—the important role of sight is demonstrated.

Response to Form and Movement: Spooner (1931), working with the bass, *Morone labrax*, which is a schooling form, found that individuals would be attracted to dead, mounted, specimens of the species but not to rough models. Similar results were obtained for the goldfish (Shlaifer, 1939, 1940). Thus, there is indicated that there may be a visual response to objects of the proper form though they are devoid of movement. Response to form is also reported by Breder (1929) for the schooling herring, *Jenkinsia*, and by Breder & Nigrelli (1935) for the aggregating sunfish, *Lepomis auritus*. On the other hand, many sexual behavior studies emphasize the importance of movement (Noble, 1934; Breder, 1936).

Experiments demonstrate that a mackerel isolated in a tank with freshly killed and mounted specimens placed in the normal swimming position, does not react to them. On the other hand, if another normal mackerel is introduced into the tank, the schooling reaction is immediately evoked.

Repeated experiments were performed with freshly killed mackerel which were manipulated by means of a long rod, the hooked end of which was inserted in the back of the fish. A normal mackerel was grouped with a mounted fish which was then manipulated so as to simulate a normal swimming animal. In only one case in 70 trials was there any response given to the dead specimen. Again, normal mackerel introduced into the experimental tank elicited immediate schooling. An olfactory basis for the lack of response to a dead, manipulated individual is not probable by virtue of the fact that the animals were freshly killed and were in fairly rapidly flowing water.

It may be concluded that normal swimming movement is an important factor in the schooling reaction. True, with normal movement a mackerel may be attracted by the body form of its neighbor but, in the absence of normal movement, form alone will not suffice. The importance of normal movement is further emphasized by the failure of a mackerel to school with a blinded individual which does not swim in the usual manner. Evidently, mackerel are sensitive to differences in motion which we can also detect and quite possibly to minor differences which we cannot observe. Nevertheless, further experimentation along these lines is in order. If simulation of swimming motion in a killed mackerel can be skillful enough to evoke a schooling reaction, neat checks might be obtained on response to form by altering in many ways the shape of the dead specimen.

Response to Color: The reaction of fishes to colors is still the subject of considerable debate. Warner (1931) criticized the lack of control of the intensity factor and deemed most of the experimental work worthy of repetition. White (1919, 1927) demonstrated that mudminnows and sticklebacks can discriminate between wave lengths and not merely intensities of light. Brown (1937) found that the large-mouthed black bass, *Huro salmoides*, responds to differences in wave lengths. Noble & Curtis (1939) demonstrated that young cichlids may be born with a greater interest in moving red discs than in moving black, blue, green or yellow ones.

Shlaifer (1939), though not differentiating between wave length and intensity, found that the group reaction in the goldfish was not in any way based on color differences or similarities. Accordingly, ex-

periments were performed with mackerel to determine whether response to color was in any way involved in the schooling behavior. Mackerel were removed from the tank and paints of various colors were applied over all of the body but the eye. They were then allowed a period of recovery from shock and were grouped in various combinations. Specimens painted blue were grouped with ones painted white, black, etc. In all cases, schooling occurred immediately with no indication whatsoever of differential response to color.

Effect of Isolation: Bowen (1932) found that the sight response of normal aggregating catfishes to one another was not completely eliminated in all individuals by 161 days of isolation. It was much less marked but was re-established in the course of a few minutes, usually after contact occurred. Catfishes isolated for only 52 days when grouped together showed no difference in behavior from those animals kept in a group.

Five mackerel were isolated for 20 days, the maximum time available before the laboratory closed. At the end of this period, two of the five were grouped together as were the remaining three. Schooling occurred immediately. If mature mackerel could be kept in isolation for much longer periods, it would be interesting to observe subsequent schooling behavior. Even more interesting would be the subsequent schooling reaction of mackerel reared in isolation from various early stages.

Discussion.

The experimental results reported above confirm the data of Parr (1927) on the visual integration of the mackerel school. Further, it is seen that only two normal individuals are necessary to begin a school. The visual response is apparently not correlated with color but is with normal swimming activity. Finally, several weeks of isolation do not induce any weakening of the schooling reaction.

The fact that two individuals suffice to begin a school, at least under laboratory conditions, may have implications for larger aggregations in nature. If schools are completely dispersed at night, their reformation in daylight would be definitely facilitated by the mutual attraction of only two fishes. In fact, again granting the break up of the school at night, without a schooling response by one solitary fish to another one, it is difficult to see how schools could reform.

In reference to the apparent visual integration of fish schools, Parr (1927) indicates that schooling pelagic fishes have eyes of large size and rather scantily equipped lateral line systems. He concedes that lateral line stimuli might come into play once the mackerel, by visual stimuli, approached each other. However, his data and those reported above on the behavior of blinded fishes would not tend to confirm this hypothesis.

Parr attributes the schooling reaction of mackerel to a simple automatic eye reflex rather than to a social instinct involving the entire school. The apparently senseless milling reaction is caused, he believes, when the school as a whole tries to make a turn of more than 180 degrees and is thus turned back on itself. This behavior pattern tends to emphasize the rather mechanical nature of the school.

Since the reaction of a mackerel to others of its kind is not to color it must be to form. However, form alone will not induce the schooling act if swimming movement is not normal. The fact that mackerel are evidently capable of detecting slight differences in movement would put the reaction of the fish on a slightly higher plane. Extensive heterotypic grouping experiments are planned which would tend to shed much light on the factors of response to various types of body form and movement. Further interesting data might be obtained by observing the reaction by an isolated mackerel to its mirror image. Following the work of Spooner (1931), the reflecting surface of the mirror could be broken by lengths of tape at definite intervals; in this way the reaction of the animal to body form which is identical with its own but not complete might be ascertained.

The condition of various types of fish schools and aggregations is summarized in a schematic diagram by Breder & Nigrelli (1935). Compared with other fishes possessing social tendencies, the schooling of mackerel is striking by virtue of its fixity. Nevertheless, the survival value of this mechanically highly integrated group is still not clear.

An interesting feature of the mackerel school is the spacing of the individuals in the group. The distance between the animals is more or less constant. A school may be greatly concentrated, however, by a sudden disturbance which produces a "fright" reaction — after being momentarily dispersed the fishes rush together in a compact mass which soon, however, returns to normal proportions. Parr (1927) states that when the fishes in a closely schooling group approach each other too closely, their images may become too large and the accompanying strenuous accommodation of the eyes may produce a negative response, thus regulating the spacing. Breder (1929) states the proposition that such fishes that depend on visual reactions for the formation of schools approach no closer to other objects than that distance at which they become clearly visible. This problem may be approached experimentally.

Whether the schooling habit is ontogenetically or phylogenetically acquired and whether the schooling or solitary state is the primitive one are important theoretical considerations. It is to be hoped that future investigation will shed some light on these problems.

Summary.

1. Although larger groups are better integrated, two individuals suffice to begin the formation of a mackerel school.

2. Blinding, darkness, and visual contact experiments indicate that the schooling reaction of the mackerel is visually integrated.

3. Mackerel display no schooling reaction to others of the same species, living or dead, which move or are moved in a manner not completely normal.

4. As far as tested, response to body color plays no role in the schooling reaction.

5. Isolation for three weeks does not eliminate or reduce the schooling proclivity.

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EXPLANATION OF THE PLATE.

Plate I.

Fig. 1. A school of chub mackerel, *Pneumatophorus grex*, in an exhibition tank under fairly strong artificial light.

Fig. 2. A flash-bulb photograph of the same school in total darkness—dispersed.

Fig. 3. Mackerel milling in light in the deep red—650 μμ to 700 μμ.

(The photographs include the upper four-fifths of the vertical depth and the central four-fifths of the length of the tank).

FIG. 1.

FIG. 2.

FIG. 3.

THE SCHOOLING BEHAVIOR OF MACKEREL: A PRELIMINARY EXPERIMENTAL ANALYSIS.

15.

Food, Eggs and Young of the Carnivorous Snail *Euglandina rosea* (Férussac).

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&

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(Plate I).

The information contained herein is based on the observation of a single *Euglandina rosea* (Férussac) which was collected April 1, 1940, at Fort Myers, Florida, by Dr. William J. Hamilton, Jr., of Cornell University. On April 11 the snail was placed in a terrarium filled with humus and soil, at Ithaca, New York. Standing water was provided to keep the air in the container moist. The individual successfully survived until December 9, 1940, when accidental overheating caused its death. During the interval of 252 days observations concerning its food habits, eggs and young were carried out.

FOOD OF *Euglandina.*

During this period of approximately 8 months the following New York land mollusks were placed in the terrarium with the carnivorous *Euglandina:* one *Mesomphix inornatus* (Say), two *Mesomphix cupreus* (Rafinesque), six *Anguispira alternata* (Say), and four newly hatched and two adults of *Triodopsis albolabris* (Say). Of these species only the *M. inornatus,* and the six *A. alternata* were devoured; the remaining snails were left untouched.

The *Euglandina* was observed during its process of feeding upon the *M. inornatus.* The predatory snail in approaching the *M. inornatus* lifted its head and anterior foot region in the air and moved them from side to side. This weaving back and forth continued for 60 seconds; during this time the greatly elongate lips were moved from side to side. Finally the *Euglandina* touched the body of the food snail, whereupon the latter contracted into its shell. The *Euglandina* then employed its anterior foot region to turn the *Mesomphix* shell over on its spire. This done, the predator entered the aperture of the food snail's shell; the posterior foot region serving to hold the rest of the body firmly to the substratum. As soon as the *Euglandina* thrust its head into the *Mesomphix* shell aperture it began to feed with a piston-like motion, apparently forcing its head firmly against the soft parts of the prey so that the radula could obtain a firm purchase. The piston motion was accompanied by a lateral movement, indicating that the *Euglandina* was working from the columellar region outward, and then back again. Because of the thinness of the *M. inornatus* shell, the feeding could be observed without great difficulty. As the body of *Mesomphix* was gradually consumed the *Euglandina* worked further into the prey's shell, until its shell presented an effective block against further entrance. During the preliminary feeding the tentacle-like lips seemed to be thrust between the body of *Mesomphix* and its shell. Finally the columellar muscle of the *Mesomphix* was torn loose and the entire upper visceral mass was observed to disappear into the buccal cavity of the *Euglandina.* The feeding process took 40 minutes from the time of entrance until all of the body of *Mesomphix* had disappeared.

After the soft parts had been consumed the lips of the *Euglandina* were observed to move about the interior of the shell as though the animal was searching for food fragments which might have been overlooked. It seems likely that the sense of smell is well-developed in *Euglandina* and possibly serves this animal in locating food. Simpson's data (1901) indicates that the sense of smell is highly developed and used to locate food by *Triodopsis albolabris* (Say). He records this species moving 18

inches in order to feed on concealed lettuce. When the *Mesomphix* was placed in the terrarium with the carnivore, the latter was 10 inches removed and was fully contracted within its shell. In 3 minutes the *Euglandina* was active, and was moving toward the *Mesomphix*. A similar phenomenon was observed when one *A. alternata* was placed in the terrarium; the *Euglandina* was again contracted and motionless, 6 inches away from the *Anguispira*. In five minutes it became active and moved toward the food snail.

The six *A. alternata* and the one *M. inornatus* utilized as food were all turned over on their apices before they were devoured.

The following writers have discussed the snail food of *Euglandina rosea*. Baker (1903) reports *Euglandina* feeding upon the large Floridan pulmonate mollusks of the genera *Liguus* and *Orthalicus*. He observed that in some instances the voracious *Euglandina* will even bore a hole in the shell of the victim in order to reach the animal, instead of entering through the prey's aperture. Rogers (1908) states that *Euglandina* devours individuals of its own species and preys chiefly upon Helices. A. Binney (1851) reports *Euglandina* feeding on half-putrid remains of a *Helix*, and on Limacies which were confined together in the same container. He, too, writes that it preys on its own kind. W. G. Binney (1885) concerning the feeding habits of *E. rosea* states, "By its [the radula's] action the soft parts of its prey are rapidly rasped away or are forced in large morsels down the oesophagus. The animal has been seen to swallow entire the half-putrid remains of a *Helix*, and to attack *Limaces* confined in the same box with it, rasping off large portions of the integument, and in some instances destroying them. In one instance an individual attacked and devoured one of its own species, thrusting its long neck into the interior of the shell and removing all the viscera. I found many specimens of *Polygra volvoxis*, [*Polygra septemvolva* Say], in the stomach of individuals collected by me at Saint Augustine, Fla."

Eggs of *Euglandina*.

In the second week of October the *Euglandina* deposited 22 eggs on the upper surface of the humus in the terrarium. This location was exposed to light, although more secretive places were available. Five of the eggs did not hatch. Because of periodic absence from the laboratory complete data on the incubation period were not obtained. The approximate incubation period was 60 to 68 days; the hatching period for individuals continued for 8 days after the first individual had emerged, 60 days after the egg had been laid.

The oval-oblong eggs were of nearly uniform size, measuring 4.25 mm. in length and from 3 to 3.25 mm. in width (Fig. 1). The egg shell is brittle and hard; no inner egg membrane is present. The egg shell is extremely rough, and is quite porous.

Young of *Euglandina*.

The young develop with their long axes coinciding with the long axis of the egg. The young break through the egg shell by means of the radula. A circular opening (Fig. 1) is first filed in the egg shell at the end surrounding the aperture of the young within. The initial hole is enlarged by use of the radula until approximately one-third of the egg shell is cut away (Fig. 2). This done, the young emerges, leaving an intact two-thirds of the shell behind. The exact amount of time required for the young to cut away enough shell to permit their escape was not observed. It is estimated, however, that with the young in question it was between 6 and 10 hours.

Little variation in size is shown in newly hatched young; of 15 that were measured the length varied .25 mm.; with the greatest length 4 mm., and the least 3.75 mm. Variation in width was also .25 mm.; the widest shell was 3 mm.; and the narrowest 2.75 mm. The largest young was 3.90 mm. in length and 2.90 mm. in width; the smallest was 3.75 mm. long and 2.75 mm. wide.

Each young has approximately two and one-fourth shell whorls upon hatching, as compared to the 6 to 8 whorls of fully mature shells. The aperture of the young is relatively large in proportion to the length of the shell, running approximately five-sevenths of the total shell length (Fig. 3). In the parent of these young the aperture was approximately equal to one-half of the total shell length. W. G. Binney (1885) concerning the length of young shells that he studied states, "In young individuals the spire forms but a small proportion of the shell, but in the old it often forms one-third of the length." A Binney (1851) comments on the shortness of the spire of young individuals, and at its enormous increase in mature shells. In an attempt to supply food for the young snails 4 small immature *T. albolabris* were placed within reach. Adult individuals of *A. alternata* were also available but individuals of neither species were touched. Apparently the lack of suitable animal food resulted in the death of the young 15 days after hatching.

Natural Habitat of *Euglandina*.

It should be understood that the observations included here were made in a habitat far from that in which *Euglandina rosea* is found. The data are, however, the most extensive to be reported on the eggs and young of *Euglandina*, and the photographic method

has not been used before to illustrate the eggs and young of this species.

The natural habitat is reported by W. G. Binney (1885) as follows, "The habits of this animal are somewhat aquatic. It is found on the sea islands of Georgia and around the keys and everglades of Florida, and in these situations the shell often attains the length of 4 inches; when found on the oyster hummocks and less humid localities it seldom exceeds 1 inch in length. Mr. Say found it in the marshes immediately behind the sand-hills of the coast. It is most readily found in the center of the clumps of coarse grass on these marshes." W. G. Binney (1885) lists the following distribution: Atlantic and Gulf States from North Carolina to Texas; Macon Springs, Georgia; Bibb County, Alabama; and Jackson, Mississippi. A. Binney (1851) indicates that it is common among the West Indian Islands. Pratt (1935) states that its distribution is from South Carolina to Texas.

ACKNOWLEDGMENTS.

The writers are indebted to Dr. William J. Hamilton, Jr., for supplying the *Euglandina.* Credit is due Mr. Arthur Smith for taking the photographs of the eggs and the young.

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EXPLANATION OF THE PLATE.

Fig. 1. Egg of *Euglandina rosea*, showing initial opening cut by radula of young within its eggshell. Note porous and rough character of the shell. × 21.

Fig. 2. Egg of young three hours later, showing egg shell cut away, revealing the immature snail within. × 23.

Fig. 3. Newly hatched young which emerged approximately 6 hours after the initial opening had been made in the egg shell. × 23.

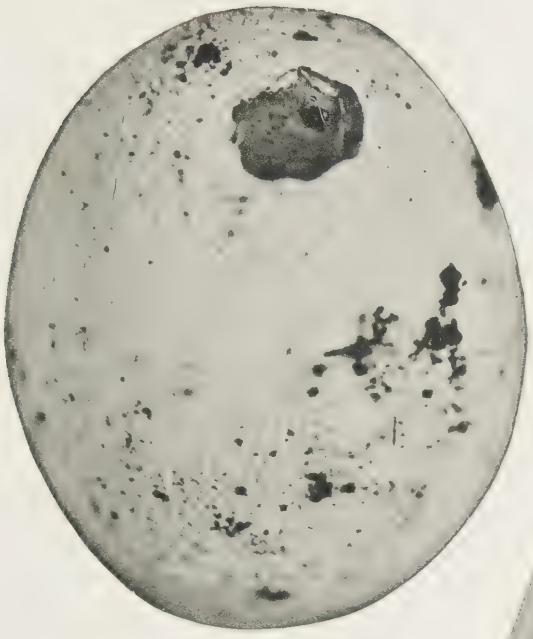

FIG. 1.

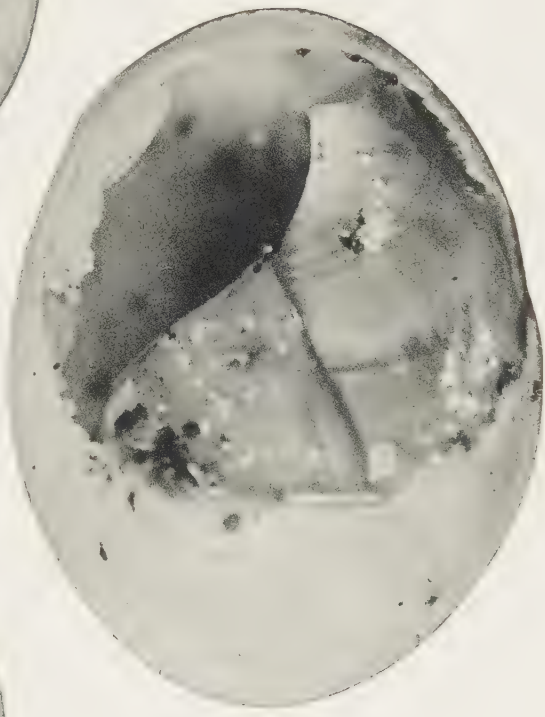

FIG. 2.

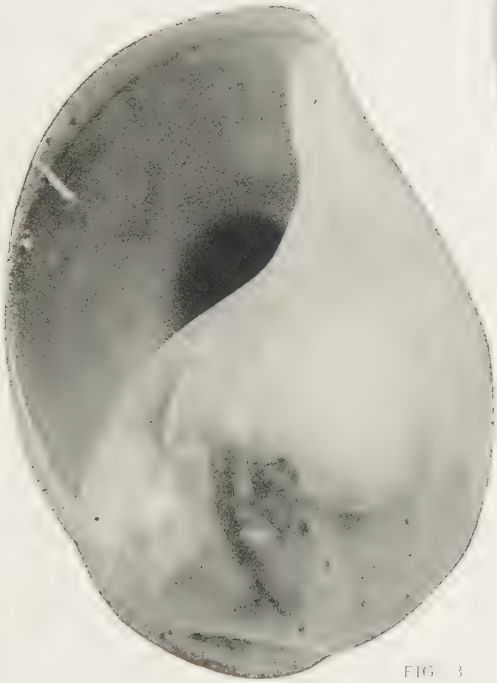

FIG. 3.

FOOD, EGGS AND YOUNG OF THE CARNIVOROUS SNAIL, EUGLANDINA ROSEA (FERUSSAC).

16.

The Anatomy and Morphology of the Hypophysis of Several Species of Ovo-viviparous Poeciliids.*

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(Plates I & II).

INTRODUCTION.

The constantly growing knowledge of the endocrine glands makes increasingly apparent the complex physiological interrelationships of the pituitary. A great deal has been reported both on the morphology and the physiology of the pituitary but most of the investigations have been concerned with mammals where such structures as the mammary glands, corpora lutea and placenta introduce many complicating factors. It would seem possible to obtain some clarification of the many problems arising from these studies by an investigation of the pituitary in forms such as lower vertebrates in which the presence of fewer accessory structures makes the problem less complex.

A survey of the literature has shown a surprisingly incomplete knowledge of the pituitary of lower vertebrates, especially of teleost fishes (Stendell, 1914; deBeer, 1926; Charipper, 1937). This becomes especially apparent when one considers the various reports relating cell types in the anterior pituitary with the reproductive cycle in mammals (Rasmussen, 1921; Wolfe & Cleveland, 1933, 1933; Charipper & Haterius, 1932; Kirkman, 1937) as compared with the meager literature of a similar nature concerning the bony fishes. With regard to the latter group, Matthews (1936) has shown that the pituitary gland of *Fundulus* is not static but undergoes variations in cell type distribution which may be related to the different seasons of the year. Cardoso (1934), also working on an oviparous form, *Pimelodus clarias*, has shown a relation between gonad size and injection of hypophyseal suspensions. Houssay (1931), investigating the ovo-viviparous teleost, *Cnesterodon decemmaculatus*, described a relationship between ovulation and secretions of the pituitary. In addition, Rojas et al. (1934) showed cyclic changes in the pituitary of *Jenynsia lineata*, another ovo-viviparous teleost. Further, the Teleostei as a group seem to offer many opportunities for descriptive investigations correlating variable hypophyseal histology and cytology to reproductive phenomena. In this group are a vast number of diminutive tropical fishes which present many evolutionary phases of reproduction from oviparity to true viviparity. This group of viviparous fishes are of particular interest because of the relatively short and usually regular reproductive cycle. These animals may be kept in large numbers in small aquaria, assuring a plentiful supply throughout the year. In addition, most of them can be bred readily so that animals in definite stages of the reproductive cycle may be easily obtained at all times.

With these facts in mind an investigation of the morphology and histology of the pituitaries of males and females of six species of ovo-viviparous teleosts was undertaken and forms the basis of the present report. The particular species examined were carefully chosen for availability and the ease with which they could be maintained and bred under laboratory conditions. In addition all these forms showed regular reproductive cycles of approximately thirty days. It is proposed that these descriptions constitute the beginning of what should prove to be an exhaustive survey and furnish a basis for future experimental investigations.

I wish to take this opportunity to express my deep appreciation to Dr. Harry A. Charipper for his generous and helpful assistance throughout the course of this investigation.

MATERIALS AND METHODS.

The pituitaries of six different species of ovo-viviparous poeciliids, *Platypoecilus variatus*, *Xiphophorus helleri* (red, and

* Accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, New York University.

green varieties), *Lebistes reticulatus, Limia tricolor, Mollienisia sphenops* and *Mollienisia latipinna* (black variety) were examined histologically. Specimens of *Mollienisia sphenops* and *latipinna* were obtained from a local dealer during the months of December, January and February. These were killed and fixed within two weeks of purchase. The other species were reared in aquaria at temperatures between 21 and 27 degrees centigrade and sacrificed at various times throughout the year.

Each fish was anaesthetized in ice water and the head severed immediately posterior to the gills and also cut just in front of the eyes. A fixing fluid composed of 18.5 cc. basic Zenker's to 1.5 cc. formalin gave the best results in about twenty hours. Following fixation, tissues were decalcified in phloroglucin 1½ hours and washed in running water 6 to 12 hours before dehydration and embedding.

Whole heads, or brain and pituitary, dissected free of all cartilage were then dehydrated and embedded in hard paraffin or tissue mat, after which they were cut at 5 micra in median sagittal, cross and horizontal sections.

The Masson technic was used almost exclusively. Timing and washing were standardized as carefully as possible in order to get comparable results on all six species. Earlier preparations were stained in Masson A ten minutes, rinsed in distilled water and destained in 1% phosphomolybdic acid 1¼ hours. They were then transferred directly to Masson C for thirty minutes, dipped in 95% alcohol, absolute alcohol, half and half absolute alcohol and xylol and then pure xylol, and finally mounted in Canada balsam. In later preparations the staining times were changed to three minutes in Masson A, thirty minutes in phosphomolybdic acid and 1 hour in Masson C. The latter timing gave better results although the staining affinities did not seem to be critically affected.

Description.

The pituitaries of the six species of poeciliids in this investigation show such striking similarities in morphology and histology that a single description will be made, using *Platypoecilus variatus* as the standard. The description will deal first with morphology and then with histology, under the headings cerebral portion (pars nervosa) and epithelial portion (pars anterior, intermedia, and uebergangsteil). Similarities and differences of the other species will then be considered separately.

I. *Platypoecilus variatus*

A. Morphology.

The pituitary is an ovoid gland, immediately behind the optic chiasma, attached to the midventral floor of the diencephalon by a short hollow stalk. There is no sella turcica but the pituitary protrudes into a depression, the hypophyseal fenestra, closed ventrally by connective tissue (Pl. II, Fig. 12).

An extremely thin meninx primitiva extends from the brain down over the stalk and over the pituitary, carrying with it numerous small blood vessels.

There are four portions of the gland, distinguishable by staining reactions and cell types, namely, pars nervosa, anterior, intermedia and uebergangsteil (Pl. II, Fig. 7). No distinct septa separate the portions. The pars nervosa is a thickened and modified portion of the floor of the diencephalon, occupying the central dorsal region of the gland. The pars anterior, like a half sphere, has its posterior surface in contact with all the other parts of the gland. In its median dorsal portion, this contact is with the nervosa. Surrounding the nervosa completely ventrally and laterally, but only its ventral half anteriorly and posteriorly, is a convoluted layer of cells, the ueberganstеil, which contacts the posterior face of the pars anterior ventral and lateral to the nervosa. The pars intermedia is a shell-like portion surrounding the uebergangsteil completely ventrally, laterally and posteriorly, forming in the latter region the blunt posterior end of the gland. Anteriorly it is contiguous with the pars anterior lateral and ventral to the contact of the latter with the uebergangsteil.

B. Histology

1. Cerebral Portion (Pars Nervosa)

The cerebral portion is composed of tissue from the floor of the diencephalon. It consists of masses of neuroglia cells and many interlacing fibres continuous through the infundibular stalk with the brain (Pl. I, Figs. 2, 4). The outer walls of the stalk are covered by a thin meninx primitiva whereas the inner walls are composed of ependyma cells which line the infundibular cavity.

The nuclei of ependyma and neuroglia cells are essentially similar, being rounded to ovoid and varying considerably in size. Each is surrounded by a well defined membrane and contains a centrally located, red-staining nucleolus and scattered pink to violet chromatin material. Nuclei are more abundant near the stalk and sparser in the central and more distal parts of the nervosa.

The cytoplasm of the ependyma cells is pale gray. Many irregular processes from them extend into the infundibular cavity. The cytoplasm of the neuroglia cells is indistinct and loosely fibrous, also staining a pale gray. Many tracts of fibres extend from the central portion of the nervosa into other parts of the gland as compact processes enclosing blood vessels which are thus distributed to the epithelial portions of the gland.

Penetration by these processes is especially heavy in the uebergangsteil and intermedia (Pl. I, Fig. 6; Pl. II, Fig. 7). In the dorsal posterior region of the nervosa the fibres run caudad through the low posterior end of the basket-shaped uebergangsteil and ramify among the cells of the pars intermedia (Pl. II, Fig. 7).

Colloid bodies of varying size and shape are characteristically present in the nervosa in varying amounts (Pl. I, Fig. 6; Pl. II, Figs. 7, 11). In the central region they are usually fairly large bodies but in the posterior region they are generally fine and granular. Their staining reaction varies in different glands from violet to pink, and both colors may be present in the same gland. In some cases large basophilic masses are filled with brilliant red-staining globules.

Free single cells, generally basophiles, are often found well within the nervosa. In some cases they appear normal but in others they show pycnotic nuclei and indistinctly outlined cytoplasm. The latter closely resemble many of the larger colloid masses.

2. Epithelial Portion

a. Pars Anterior

The pars anterior is composed almost entirely of orange-red acidophiles, except for a tongue-like portion adjacent to the nervosa in the median dorsal portion of the gland. The acidophiles are closely packed, showing no definite arrangement into cords or tubules (Pl. II, Fig. 7). They vary in shape from rounded to ovoid to spindle shaped. Their size is also variable. The cytoplasm contains fine orange-red granules. The nuclei vary in size in relation to the size of the cells containing them. Their shapes range from spherical to elongate and their position may be central or apical. Within each nucleus are one or two red-staining spherical nucleoli surrounded by red-staining chromatin granules in a clear hyaloplasm. The tongue-like strip of tissue (Pl. I, Fig. 2) is a sheet several layers thick, roughly "V" shaped, which fits into the uebergangsteil with which it is continuous laterally and ventrally. Its posterior surface is in contact with the pars nervosa from which it is clearly separated by a membrane, and its anterior surface is in contact with the acidophilic part of the pars anterior. Here the delineation is less definite as many of the acidophiles penetrate the tongue-like portion irregularly. Many blood vessels pass through this sheet, enclosed within processes from the nervosa. The cells of this layer bordering the nervosa tend to be columnar while those within the sheet are poorly defined. The cytoplasm has a fleecy appearance and stains a pinkish-gray color. Nuclei are ovoid to spherical, containing a centrally located nucleolus and scattered granular chromatin, both of which stain similarly to the cytoplasm.

b. Pars Intermedia

The pars intermedia is composed entirely of basophiles. Its cytology is variable, the posterior part often showing a large number of basophiles, larger and more clearly defined than the cells of its middle portion, which closely resemble basophiles of the uebergangsteil. The cytoplasm of these larger ovoid to spherical cells ranges from violet to blue and appears homogeneous. Nuclei are roughly spherical, often having indentations which give them a vesicular appearance. They contain granular, faint pink-staining chromatin and a centrally located red-staining nucleolus. The rest of the intermedia cells are smaller and usually indistinctly outlined, their stainability varying from pale gray-blue to a deep blue. Small spherical vacuoles are often present. No special arrangement is apparent in these cells (Pl. I, Fig. 6; Pl. II, Figs. 7, 8). The nuclei are small and ovoid to spherical with well defined membranes in which is a granular chromophobic chromatin surrounding a centrally located red nucleolus. Nervosa processes enclosing blood vessels penetrate the middle region of the pars intermedia after passing through the uebergangsteil, while loose wavy masses of fibers penetrate the dorsal posterior portion directly (Pl. II, Fig. 7).

Besides varying in cell type, the pars intermedia varies in size. In some it is large while in others it is much reduced, forming a thin layer over the uebergangsteil and a small posterior part.

C. Uebergangsteil

The uebergangsteil is the most changeable part of the gland, varying both as to size and as to proportions of its three cell types, basophiles, acidophiles and chromophobes (Pl. I, Fig. 6; Pl. II, Figs. 7, 8). Sometimes single cells or islets of cells lie free among the fibres of the pars nervosa.

The most common type of cell is a large polygonal or round deeply staining carmine red cell with well defined borders. The cytoplasm is filled with coarse carmine-colored granules. The nuclei are spherical to ovoid with a fine granular light red chromatin reticulum surrounding a centrally located brilliant red nucleolus. In some pituitaries these cells were present almost exclusively (Pl. I, Fig. 6). Other glands have an uebergangsteil which is heavily basophilic with a few scattered acidophiles and chromophobes. In such glands the stainable material of the acidophiles is often clumped and peripheral in location. The basophiles closely resemble the acidophiles in size and shape and their nuclei appear identical (Pl. II, Fig. 8). Their cytoplasm is optically homogeneous and varies in staining capacity

from pale gray-blue to deep blue. In some glands basophiles are present only in one or two spherical, centrally located masses which may be exclusively basophilic or may contain some acidophiles also. Chromophobes are smaller, poorly outlined and faintly pink-staining cells, more prevalent, if present at all, in the ventral region of the uebergangsteil. Their nuclei are similar to those of the chromophiles.

II. *Xiphophorus helleri.*

The pituitary of *Xiphophorus* is typically deeper dorso-ventrally than that of *Platypoecilus variatus* and is more concave at its dorsal surface (Pl. I, Fig. 4).

Cell types of the four portions of the gland correspond to those described above with the exception that several small patches of basophiles are usually present in the pars anterior (Pl. I, Fig. 4). These have a small amount of fleecy, indistinctly outlined bluish-gray cytoplasm and nuclei with a coarsely granular, similarly colored chromatin reticulum. They resemble quite closely the cells of the tongue-like portion of the pars anterior.

Another difference from *Platypoecilus* is found in the arrangement of the cells of the uebergangsteil. In *Xiphophorus* cells of this region form a deep mass heavily penetrated by small curving fibrous tracts enclosing blood vessels, which, in median sagittal sections, appear to divide the tissue into rounded islands (Pl. I, Fig. 4). In *Platypoecilus* the uebergangsteil is a thinner, more convoluted layer through which the nervosa processes pass in a more direct manner.

III. *Lebistes reticulatus*

The pituitary of *Lebistes reticulatus* is slightly more elongate and dorso-ventrally flattened than either of the preceding (Pl. I, Fig. 5; Pl. II, Fig. 10). Fewer nervosa processes penetrate the tongue-like portion of the pars anterior than is the case in *Platypoecilus variatus.* The uebergangsteil is more of a convoluted layer than in *Platypoecilus* (Pl. II, Fig. 10), and is heavily penetrated by nervosa processes with their blood vessels. One or two conspicuous masses of basophiles are characteristically present in the central region of the uebergangsteil.

In the pars intermedia of *Lebistes* a broad fibrous tract often reaches from the posterior end of the nervosa, postero-ventrally to the median ventral border of the gland. This is not shown in the figures of *Lebistes* but may be seen in Pl. I, Fig. 3, of *Mollienisia sphenops,* and Pl. II, Fig. 9, *of Limia tricolor.*

Cell types and arrangement are almost identical with those of *Platypoecilus.* However, patches of pale basophiles, similar to those of *Xiphophorus,* are occasionally present in the pars anterior, especially in the Trinidad variety of *Lebistes.*

IV. *Limia tricolor*

The pituitary of *Limia tricolor* is similar in shape to that of *Xiphophorus* (Pl. II, Fig. 9). The pars anterior is heavily penetrated by nervosa processes as in the case of *Platypoecilus.* A broad tract of nervosa fibres cut through the uebergangsteil and pars intermedia to the median ventral surface of the gland as in the case of *Lebistes.*

Cell types correspond to those in *Xiphophorus,* sparse groups of basophiles being characteristically present in the pars anterior.

V. *Mollienisia sphenops*

The pituitary of *Mollienisia sphenops* is different in shape from all the others, being almost perfectly rounded, and flattened dorso-ventrally, (Pl. I, Fig. 3; Pl. II, Fig. 12). Like *Lebistes* and *Limia* it has a broad nervosa tract extending postero-ventrally through the uebergangsteil and pars intermedia to the median ventral surface of the gland. Occasional pale basophiles are found scattered in the pars anterior as in the case of *Xiphophorus,* and are also present along the nervosa processes entering the pars anterior.

The uebergangsteil is more highly convoluted than in *Platypoecilus* and *Lebistes,* and often a linear arrangement of carmine-colored acidophiles forms a border between the nervosa and basophiles and acidophiles of the deeper layer of the uebergangsteil.

VI. *Mollienisia latipinna*

The pituitary of *Mollienisia latipinna* is most similar in shape to that of *Xiphophorus helleri* (Pl. I, Fig. 1). The extension of the infundibular cavity, the recessus hypophyseus, penerates the gland more deeply than in any of the other species. Many nervosa processes with their blood vessels penetrate the tongue-like portion of the pars anterior to be distributed throughout the basophilic part of the pars anterior. Along these processes, and scattered in small groups throughout the mass of acidophiles, are pale basophiles, a condition similar to that found in *Mollienisia sphenops.*

Discussion.

I. Anatomy

Pituitary morphology and histology are fundamentally similar in the six species of poeciliids examined. The glands most closely resemble those of the egg laying poeciliid, *Fundulus,* and the ovo-viviparous poeciliid, *Jenynsia lineata,* as described by Scruggs (1939) and Rojas et al. (1934) respectively.

The infundibular stalk is highly variable among teleosts, being almost non-existant in *Mormyrus* (Stendell, 1914), the pituitary

being held close to the brain, and short in *Fundulus* (Matthews, 1936) and *Carassius auratus* (Bell, 1937, 1938; Levenstein, 1939; Scruggs, 1939). In *Lophius piscatorius* (de Beer, 1926) the stalk reaches its highest development, extending anteriorly for a considerable distance. It may be solid as in *Carassius* or hollow as in *Pungitus* (Scruggs, 1939) and in the poeciliids described here.

No structure comparable to a sella turcica is present in the teleosts. In *Fundulus* (Matthews, 1936) and *Carassius* (Bell, 1938; Levenstein, 1939) the pituitary is protected by the parasphenoid bone. The poeciliid crania of this investigation differ from the above, being of the platybasic type as described by Kingsley (1936). The cranium floor is composed of calcified connective tissue which spreads out laterally over the trabeculae cranii. The pituitary projects ventrally into the hypophyseal fenestra, a depression in the floor of the cranium.

A. Pars Nervosa

The pars nervosa protrudes into the gland at different angles in various teleosts. In *Carassius* (Bell, 1938; Levenstein, 1939) and in *Cyprinus* (Scruggs, 1939) the gland is tilted forward and the nervosa runs anteriorly. In *Ameiurus nebulosus* (Scruggs, 1939) the pituitary is tilted backward and the nervosa runs posteriorly. In the poeciliids investigated here the pituitary is directly beneath the infundibular stalk and the nervosa is directed vertically downward.

A recessus hypophyseus, representing an extension of the infundibular cavity into the nervosa, is present in *Jenynsia* (Rojas et al., 1934), *Fundulus* (Matthews, 1936), and in the poeciliids of this investigation. It is lacking in some teleosts, as *Carassius* (Bell, 1938; Levenstein, 1939) and *Ameiurus* (Scruggs, 1939).

There is also much variation in the number of nervosa processes given off and in their penetration of the various portions of the gland. In *Pseudopleuronectes americanus* and *Cyprinus carpio* (Scruggs, 1939) the nervosa processes are limited exclusively to the pars intermedia; in *Fundulus*, to pars intermedia and uebergangsteil; in *Carassius*, *Jenynsia* and the poeciliids of this report, the nervosa processes go to all parts of the pituitary.

B. Pars Anterior

The proportions, contacts and positions occupied by the various portions of the pituitary in different teleosts are highly variable. In *Carassius* (Bell, 1938; Levenstein, 1939; Scruggs, 1939) and in *Cyprinus carpio* (Stendell, 1914; Scruggs, 1939) the pars anterior is small, dorsal in position and makes contact with the uebergangsteil mostly and the nervosa only in a limited area. In *Notemigonus* (Scruggs, 1939) it is large and anterior in position, making contact with the uebergangsteil and the main portion of the nervosa. In *Ameiurus nebulosus* the pars anterior is small. It is anterior and ventral in position, again making contact with uebergangsteil and nervosa (Scruggs, 1939). In the fishes of the investigation the pars anterior is very large, anterior in position, and touches nervosa, uebergangsteil and pars intermedia. The variations, however, are more apparent than real, being due in large part to a tilting of the pituitary either backward or forward.

A pars anterior has been reported for all teleosts examined except *Esox niger* (Scruggs, 1939) and *Fundulus* (Matthews, 1936). However, in his 1937 paper Matthews decided that the anterior portion of the pituitary, previously called the uebergangsteil, was actually the pars anterior. This was substantiated by Scruggs (1939) on the basis of staining reactions. In the case of *Esox niger* Scruggs found no portion taking a stain like that of the pars anterior of other teleosts; Stendell (1914), however, describes a small pars anterior for *Esox lucius*.

C. Pars Intermedia

The pars intermedia of teleosts has usually been identified by its close relationship with the pars nervosa. Stendell (1914) shows an intimate relationship of the two parts in the primitive *Mormyrus*, while in the higher teleost, *Esox lucius*, the pars intermedia is more posterior in position and retains its association with the nervosa by means of nervosa processes extending out into it. It extends forward ventrally, reaching or nearly reaching the posterior end of the pars anterior, thus surrounding the uebergangsteil ventrally. While Matthews (1937) divides the pituitary of *Fundulus* into only two epithelial portions, a pars anterior and a pars intermedia, Scruggs (1939) shows that the latter portion may be differentiated, by the Dawson & Friedgood (1938) method, into two portions comparable to the pars intermedia and the uebergangsteil of other teleosts. The pituitary of the poeciliids of this investigation compare with that of *Fundulus* as found by Scruggs, having an uebergangsteil adjacent to the pars nervosa and a pars intermedia which surrounds it laterally, ventrally and posteriorly. Connection with the nervosa is direct posteriorly and by means of nervosa processes extending through the uebergangsteil centrally and anteriorly.

D. Uebergangsteil

The uebergangsteil is present in some cyclostomes and all teleosts. It is highly variable in the latter, the simplest condition being found in *Mormyrus* where the

pars anterior, uebergangsteil and pars intermedia are arranged in linear order with no distinct boundaries between them. In *Gasterosteus* (Bock, 1928) connective tissue septa separate the parts. In *Carassius auratus* (Bell, 1938) the uebergangsteil is very large, bordered by connective tissue, and forms most of the anterior part of the gland. In *Esox niger* (Scruggs, 1939) no pars anterior is reported and the uebergangsteil occupies the antero-dorsal region of the gland, being in size, shape and location similar to the pars anterior of *Carassius auratus*. The uebergangsteil of the poeciliids investigated here has no connective tissue septa, is moderately large, and as in most teleosts, lies between the pars anterior and the pars intermedia, a portion of the latter extending over it, however, in the middle region of the gland. It is highly variable in individuals of the same species, being a large deep layer in some, a thinner layer in others. In *Lebistes, Platypoecilus* and *Mollienisia sphenops* it tends to be highly convoluted while in the other species examined it is a thicker, less folded layer.

II. Histology

A. Pars Nervosa

Stendell (1914) described the nervosa most completely. It is composed chiefly of neuroglia cells. The infundibular cavity and recessus hypophyseus are lined with primitive ependyma cells having protoplasmic extensions both basally and distally. Bock (1928) confirms these findings in *Gasterosteus*. Through the neuroglia network Stendell describes lymph tracts, blood vessels and connective tissue. Stolon-like nervosa processes extend to all parts of the gland. He interprets the structure of the nervosa as providing the means of absorption of pars intermedia secretions by way of lymph and blood vessels. Colloid masses among nervosa fibres, he believes represent secretion of degenerating pars intermedia cells. Collin (1924), in mammals, Florentin & Weiss (1931), Florentin (1934) and Rojas et al. (1934), in teleosts, hold the same theory of secretion and absorption. The structure of the pars nervosa of the poeciliids investigated here confirms that of the above authors. Nervosa processes ramify throughout all portions of the pituitary, especially the pars intermedia. Colloid masses of varying size and amount are present in the nervosa and pars intermedia. Matthews (1936), Levenstein (1939), Scruggs (1939) and others call attention to masses of colloid in the nervosa. Stendell (1914) also notes many free cells of the pars intermedia lying in the nervosa and believes that they degenerate into colloid. In the present work a number of free cells were seen lying in the nervosa, some appearing degenerate and closely resembling colloid masses.

B. Pars Anterior

The pars anterior of teleosts differs greatly from that of other vertebrates, consisting almost entirely of acidophiles, with sometimes a scattering of basophiles. Entirely basophilic pars anteriors have been reported in the eel, *Cyprinus, Esox lucius* and in *Carassius* by Tilney (1911), Stendell (1914) and Bell (1938). However, modern technics have shown these same portions to be predominantly acidophilic (Florentin & Weiss, 1931; Scruggs, 1939; Levenstein, 1939). These discrepancies thus appear to be due to differences in staining technics.

In the present work the pars anterior is almost entirely acidophilic. Occasional single or small groups of pale basophiles may be present, especially in *Xiphophorus, Limia* and the *Mollienisias*. Their scarcity precludes any great physiological significance. An additional type of cell, an orange acidophile, is described in some species by Scruggs, using the Dawson & Friedgood technic. These are difficult to interpret since in some species they are the predominant or exclusive type of cell present in the pars anterior while in others a few are present among a background of carmine-staining cells. Also similar orange cells are described in the pars intermedia of some species.

The arrangement of pars anterior cells differs greatly in the various groups of teleosts, varying from a compact condition with no special arrangement as found in the poeciliids in this report to a tubular distribution in which the cells are arranged around lumina, as in the eel (Tilney, 1911) and in the Salmonidae (Scruggs, 1939). An intermediate condition, where the cells are arranged in solid cords, is seen in the cod (Herring, 1908). In those forms in which cord or tubule arrangement is present the cords or tubules are separated from one another by connective tissue septa. Such separation is difficult to discern, or absent in the compact type of gland.

A pale basophilic or chromophobic tongue-like portion of the pars anterior has received little attention; Bock (1928) reports it in *Gasterosteus* and Scruggs refers to it briefly in the Salmonidae, *Fundulus* and *Pungitus*. This portion is present in all the Poeciliidae investigated in the present report, occupying a position in the dorsal half of the gland, between the acidophilic part of the pars anterior and the pars nervosa. It is a layer several cells in thickness, the cells adjacent to the pars nervosa being ependyma-like, oriented with their long axes perpendicular to their contact with the nervosa.

C. Pars Intermedia

Most of the recent work on teleost pituitaries shows the pars intermedia to be composed almost entirely of small pale-staining

basophiles. Scruggs (1939), using the Dawson & Friedgood technic, also found a varying number of orange cells. In *Esox*, Scruggs describes basophiles, orange cells and carmine cells; in *Fundulus*, basophiles, chromophobes and orange cells. Matthews (1936) describes acidophiles of the pars intermedia lining the nervosa processes. These cells, however, seem to belong to the uebergangsteil as described by Scruggs in the same species, rather than to the pars intermedia. The poeciliids investigated in the present report closely resemble *Fundulus* in pituitary structure. In these the pars intermedia, with the Masson stain, is entirely basophilic. The uebergangsteil lies between part of the intermedia and the nervosa, and deep red cells of the uebergangsteil often line the nervosa processes.

The arrangement of cells in the pars intermedia is generally agreed to by all investigators. In *Anguilla* and *Esox* (Stendell, 1914) polygonal cells form a compact stratum traversed by many nervosa processes. Bordering the nervosa processes the cells become cuboidal to columnar, forming an epithelium. Bell (1938) describes the cells of the pars intermedia of *Carassius* as ovoid or polygonal but forming an epithelial layer about the nervosa processes. Scruggs describes the intermedia cells of *Carassius* as indistinctly outlined. In the present work the pars intermedia shows a compact arrangement with polygonal or indistinctly outlined cells. An epithelial arrangement may occasionally be found adjacent to nervosa processes.

The pars intermedia varies both in structure and in the proportion of the gland which it occupies. Rojas et al. describe the disappearance of typical cells in the posterior portion and the appearance of colloid droplets in this location. The same condition is noted in the pars intermedia of the poeciliids investigated here. The dorsal portion of the intermedia is sometimes filled with small colloid droplets and few typical cells are present. Herring (1908) was the first to note such colloid in his work on the cod, and since then Stendell (1914) and many others have called attention to its presence. Scruggs (1939) reports a decrease in the size of the pars intermedia of *Fundulus* in January as compared with June. The pars intermedia of the poeciliids investigated here shows considerable variation in the proportion of the gland which it forms. In some cases a portion of its territory is occupied by large basophiles which appear to belong to the uebergangsteil.

D. Uebergangsteil

The uebergangsteil is composed of acidophiles and basophiles in the eel and in *Mormyrus*, acidophiles predominating in the former and basophiles in the latter (Stendell, 1914). In the stickleback (Bock, 1928) chromophobes and a few basophiles are present. Scruggs (1939) finds no acidophiles in the uebergangsteil of the eel, only basophiles and chromophobes being present. In most of the teleosts examined by him, he reports deep-staining acidophiles and basophiles, and chromophobes. The poeciliids examined here have the three characteristic cell types.

Uebergangsteil cells may form a compact mass with acidophiles and basophiles scattered in groups (Bell, 1937, 1938; Charipper, 1937; Levenstein, 1939; Scruggs, 1939) or a folded epithelial configuration as seen in Scruggs' figures of the Centrarchidae and Poeciliidae. A similar condition is seen in the figures of Matthews (1936), Rojas et al. (1934) and in the poeciliids of this investigation.

Cell type proportions are highly variable in the uebergangsteil of any single species. Bock (1928), Rojas et al. (1934), Matthews (1936) and Scruggs (1939) all call attention to changes in cell types. Matthews finds seasonal changes in the proportionate number of acidophiles and basophiles of *Fundulus*. A particular type of basophile is present in the posterior part of the pars intermedia only at certain times of the year. Scruggs also reports seasonal changes in the *Fundulus* pituitary and describes the migration of large deep-staining basophiles which invade the posterior part of the pars intermedia. In this investigation, large basophiles are present in many specimens in the posterior part of the pars intermedia, similar to those of the uebergangsteil. Also great variability is manifested in percentage of basophiles and acidophiles in different individuals, the uebergangsteil of some being almost entirely basophilic, others almost entirely acidophilic, still others having varying proportions of each. These variations are suggestive of a regulated cyclic variation which may be related to the reproductive cycle. However, cell counts failed to establish any definite relationship between stages of the reproductive and percentage of cell types.

E. Colloid

Herring (1908) first called attention to colloid in the cod pituitary. Stendell (1914) emphasized the functional relationship between nervosa and pars intermedia and postulates two methods of secretion by the intermedia, one by release of minute colloid droplets which are absorbed by the nervosa processes. In the second, intermedia cells wander into the nervosa and disintegrate, forming secretory material which is absorbed by the nervosa. Rojas et al. (1934) and Florentin (1934) likewise describe holocrine secretion in teleost pituitaries. Rojas states that cells of the posterior part of the pars intermedia degenerate and only colloid is left in their place. Matthews (1936) de-

scribes acidophilic colloid in the nervosa which closely resembles the secretory inclusions of the acidophiles of the pars "intermedia" as described by him. In the poeciliids investigated here the posterior portion of the pars intermedia is highly colloidal in many specimens and few cells are present. In others the region is cellular and has little or no colloid. Also single cells or small groups of cells from the uebergangsteil are sometimes present in the nervosa, many of them apparently in the process of disintegration and closely resembling some of the colloid masses. Thus both types of secretion as interpreted by Stendell (1914) are confirmed in this report.

F. Blood Supply

Bock (1928) and Bell (1938) describe poor vascularization in the pituitaries of *Gasterosteus* and *Carassius* respectively. On the other hand, a heavy vascular supply is described in the eel (Tilney, 1911) and *Cyprinus* and *Esox* (Stendell, 1914). The poeciliids investigated here most closely resemble the eel in vascularity. Large vessels in the nervosa radiate outward in all directions within the nervosa processes, and penetrate all parts of the gland.

G. Homologies

Establishment of homologies of the parts of the teleost pituitary with those of mammals is desirable as a prelude to experimental work. Stendell (1914), Charipper (1937), Bell (1938) and Levenstein (1939) homologize the teleost uebergangsteil with the mammalian pars anterior. Levenstein shows two types of chromophobes in the uebergangsteil having Golgi corresponding to those of the acidophiles and basophiles of this portion. This compares with the findings of Addison (1916), Atwell (1929), Severinghaus (1933) and Kirkman (1937) in mammals. The present work shows three types of cells in the teleost uebergangsteil similar to those in the mammalian pars anterior. The pars intermedia of mammals and teleosts occupies a similar position and is almost exclusively basophilic.

The pars anterior of teleosts is interpreted by Bock as a portion unrelated to the pars anterior of higher vertebrates. Charipper (1937) and Bell (1938) compare it with the pars tuberalis of higher forms on the basis of location, cord-like arrangement of cells and basophilic staining reaction. Scruggs (1939), using the Dawson & Friedgood technic, finds the teleost pars anterior to be acidophilic, however, while the pars tuberalis of mammals is chromophobic with the same technic. In the present investigation a tongue-like portion of the pars anterior, occupying a position along the dorso-anterior surface of the nervosa, close to the infundibular stalk and brain, takes a pale basophilic or chromophobic stain. Bock (1928) and Scruggs (1939) describe a similar portion in several teleosts. This portion seems to compare more favorably with the pars tuberalis of higher forms. If this be the case, then the rest of the pars anterior can be considered only as a separate structure characteristic of teleosts and of some cyclostomes.

Summary and Conclusions

1. The pituitaries of the six species of ovoviviparous poeciliids conform, in the presence and general disposition of epithelial and nervous portions, with the structure reported for other teleost fishes. The four portions are the pars anterior, pars intermedia, uebergangsteil and pars nervosa.
2. Boundaries between the parts are established by abrupt changes in cell type rather than by connective tissue septa.
3. The pars nervosa consists of a solid mass of fibrous tissue and neuroglia cells. It occupies the dorsal and central portion of the pituitary gland and sends solid root-like processes to all the epithelial portions. Within the nervosa are varying amounts of colloid, usually violet-colored, large, amorphous masses and some finer acidophilic granules.
4. The pars anterior is composed almost entirely of small orange-red acidophiles which show no special arrangement into cords or nests. A tongue-like strip of faintly basophilic or chromophobic cells separates the acidophilic portion from the pars nervosa throughout the dorsal half of the gland.
5. Only occasional single or small groups of basophiles are present in the pars anterior of *Xiphophorus helleri, Limia tricolor, Mollienisia latipinna* and *Mollienisia sphenops*, and in a few *Lebistes*.
6. The pars intermedia consists of small faintly-staining basophiles showing no special arrangement. The posterior region is less cellular and more heavily penetrated by fibres from the nervosa and takes a violet color with the Masson stain. The middle portion is heavily cellular and stains light blue. Many small vacuoles but little or no colloid are present in this region.
7. The uebergangsteil is a thick layer of cells surrounding the pars nervosa completely laterally but only on its ventral half anteriorly and posteriorly. It may form a highly convoluted layer typical of *Lebistes* and *Platypoecilus variatus*, or a thicker, less folded layer as in *Xiphophorus helleri*. In all cases many strands of the nervosa penetrate it to reach the middle portion of the pars intermedia. Large granular acidophiles, large and more homogeneous basophiles

and occasional chromophobes constitute the cellular population of this region.

8. There appears to be a regulated variation of the pars intermedia and the uebergangsteil in which the proportions occupied by the two parts varies inversely. Not only do the proportions of the two parts change but also the ratio of basophiles and acidophiles in the uebergangsteil changes. No correlation was established, however, between these changes and stages of the reproductive cycle.
9. The pars anterior, intermedia and nervosa have an abundant blood supply. The uebergangsteil has no direct blood supply, but it is penetrated in many places by strands of the nervosa tissue, each of which ensheathes a blood vessel. The many foldings of the uebergangsteil layer bring most of the epithelial tissue in close contact with the blood vessels. In cases where the uebergangsteil is not convoluted the nervosa processes with their blood vessels show heavy anastomoses with each other, thus dividing the epithelium into many patches or islands bordered by blood vessels.

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EXPLANATION OF THE PLATE.

All material illustrated has been fixed with a modified Helly's fluid, stained with the Masson stain, and cut at 5 micra (except Fig. 3 which was cut at 7 micra).

Plate I.

Fig. 1. Median sagittal section through the infundibular stalk of a female *Mollienisia latipinna*, showing the recessus hypophyseus, nervosa processes entering the pars anterior and other portions of the gland. × 140.

Fig. 2. Median sagittal section through the pituitary of *Platypoecilus variatus* showing pars nervosa and part of pars anterior. Neuroglia cells and fibres are visible in the pars nervosa. The tongue-like portion of the pars anterior is clearly visible. × 610.

Fig. 3. Median sagittal section through the infundibular stalk of *Mollienisia sphenops* showing nervosa tract descending from the posterior region of the pars nervosa to the ventral border of the gland. A patch of basophiles is present in the pars anterior, adjacent to a nervosa process. The convoluted arrangement of the uebergangsteil is apparent. Colloid is abundant both in the pars nervosa and in the posterior region of the pars intermedia. × 250.

Fig. 4. Median sagittal section through the infundibular stalk of *Xiphophorus helleri* showing the four portions of the gland. Small gray patches of basophiles and the gray tongue-like portion can be seen in the pars anterior. Also, small fibrous tracts carrying blood vessels can be seen penetrating the uebergangsteil. × 175.

Fig. 5. Median sagittal section through the infundibular stalk of the pituitary of a female *Lebistes reticulatus* showing the different portions of the gland. The pituitary is more elongate and dorso-ventrally flattened than in the other species. × 300.

Fig. 6. Cross section through the infundibular stalk of *Platypoecilus variatus* showing the sharp demarcation of the uebergangsteil (dark staining cells) from the middle region of the pars intermedia. Colloid bodies and nervosa processes can be seen in the nervosa. × 160.

Plate II.

Fig. 7. Median sagittal section through the infundibular stalk of a male *Platypoecilus variatus*, the four portions of the gland. The pars anterior is composed almost completely of dark-staining acidophiles. In the pars nervosa colloid bodies are seen among the neuroglia cells and fibres. The uebergangsteil is composed of basophiles and acidophiles, some of which invade the pars intermedia ventrally. × 220.

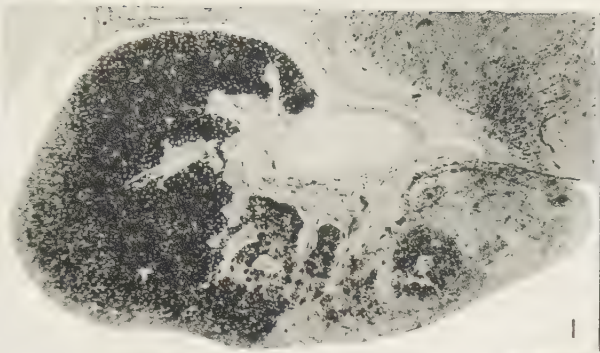
Fig. 8. Median sagittal section through the pituitary of *Platypoecilus variatus*, showing the large acidophiles and basophiles of the uebergangsteil. Below them are the small basophiles of the pars intermedia. × 900.

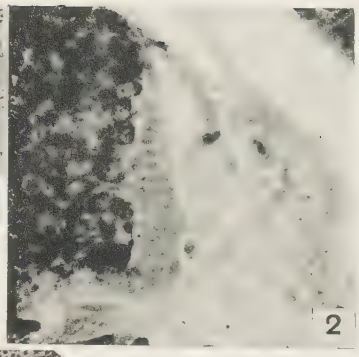
Fig. 9. Median sagittal section through the pituitary gland of *Limia tricolor*. A tract of pars nervosa fibres can be seen penetrating to the ventral border of the gland. Many colloid masses are present in this tract and in the dorsal posterior region. × 240.

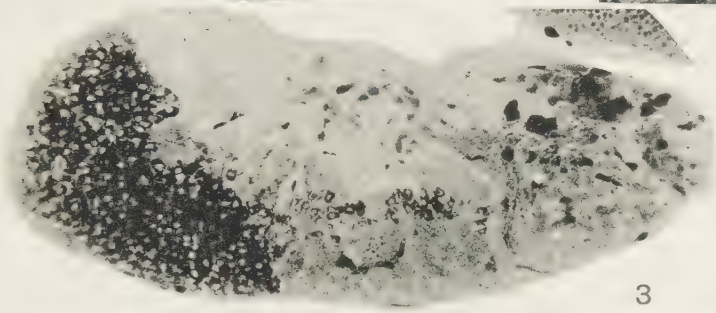
Fig. 10. Cross-section through the infundibular cavity of the pituitary of *Lebistes reticulatus*, showing the highly convoluted uebergangsteil. × 300.

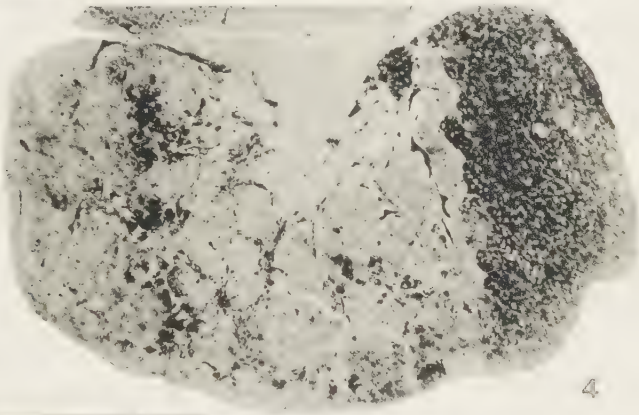
Fig. 11. Cross-section through the mid-region of the pituitary of *Platypoecilus variatus*, showing the pars nervosa surrounded by the uebergangsteil. Colloid bodies are prominent in the pars nervosa. Numerous blood vessels carried in nervosa processes penetrate the uebergangsteil. × 460.

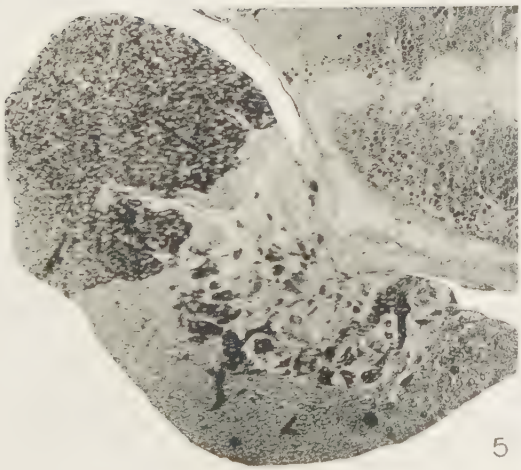
Fig. 12. Cross-section through the infundibular stalk of the pituitary of *Mollienisia sphenops*, showing a part of the pars anterior at the right. Beneath the gland may be seen the hypophyseal fenestra. × 160.

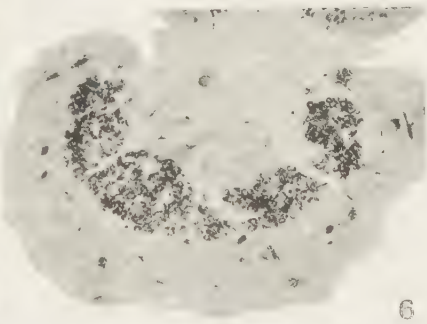




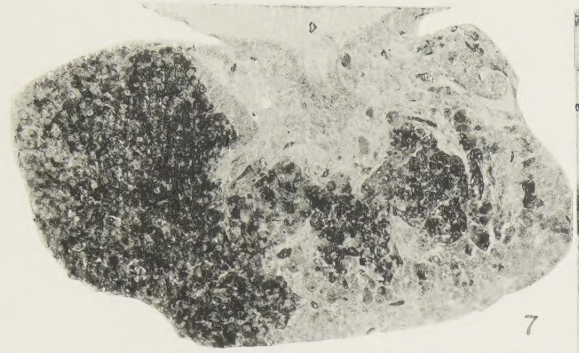


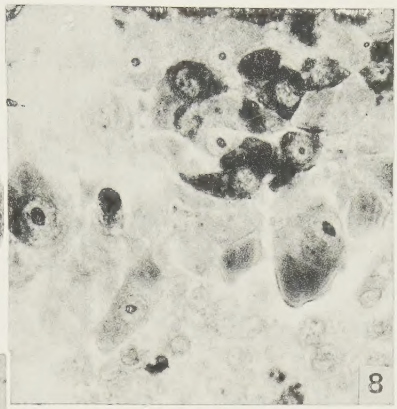


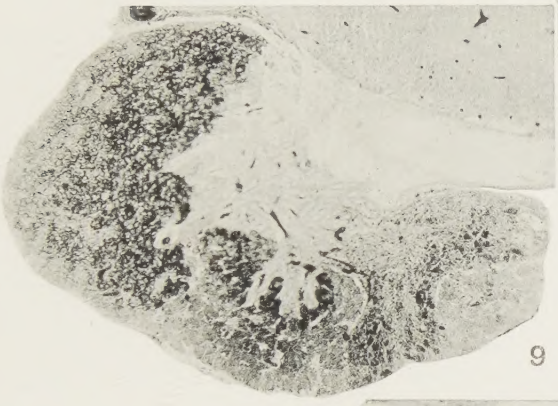


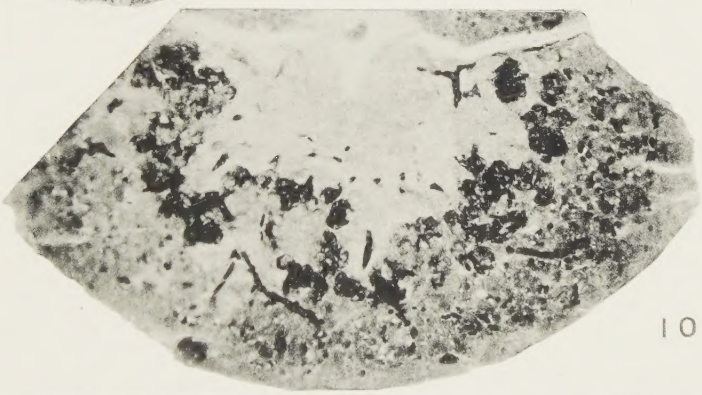


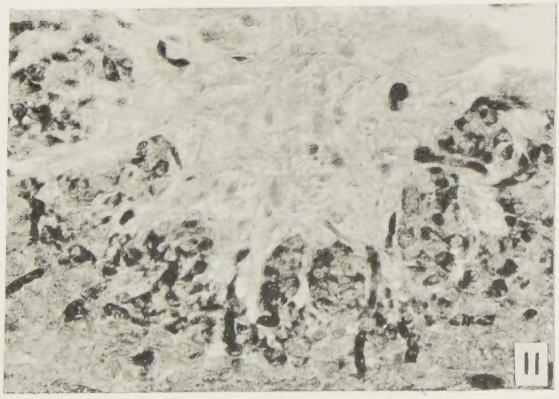
THE ANATOMY AND MORPHOLOGY OF THE HYPOPHYSIS OF SEVERAL SPECIES OF OVO-VIVIPAROUS POECILIIDS.

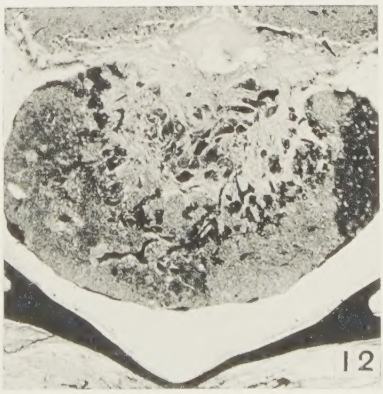












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